Vision Sciences Society

14th Annual Meeting, May 16 -21, 2014

TradeWinds Island Resorts, St. Pete Beach, Florida

Abstracts

Contents

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Sessions Overview

Abstract Numbering System

Each abstract is assigned a unique 4 to 5 digit number based on when and where it is to be presented. The format of the abstract numbering is DT.RN (where D is the Day, T is the Time, R is the Room and N is the Presentation number).

First Digit - Day	Second Digit - Time Period	Third Digit - Room	Fourth/Fifth Digits - Number
2 Saturday	1 Early AM talk session	1 Talk Room 1	1, 2, 3... For talks
3 Sunday	2 Late AM talk session	2 Talk Room 2	01, 02, 03... For posters
4 Monday	3 AM poster session	3 Jacaranda Hall	
5 Tuesday	4 Early PM talk session	4 Banyan Breezeway	
6 Wednesday	5 Late PM talk session	5 Pavilion	
	6 PM poster session		

Examples:
21.16 Saturday, early AM talk in Talk Room 1, 6th talk
36.513 Sunday, PM poster in Banyan Breezeway, poster board 513
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Note: Two digits after the period indicates a talk, three digits indicates a poster (and is also the number of the poster board).

Member-Initiated Symposia

Schedule Overview

Friday, May 16, 12:00 - 2:00 pm

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Vision and eye movements in natural environments

S2, Pavilion

Beyond the FFA: The role of the ventral anterior temporal lobes in face processing

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The visual white-matter matters! Innovation, data, methods and applications of diffusion MRI and fiber tractography

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What are you doing? Recent advances in visual action recognition research

S6, Pavilion

Understanding representation in visual cortex: why are there so many approaches and which is best?

S1 Vision and eye movements in natural environments

Friday, May 16, 12:00 - 2:00 pm, Talk Room 1

Organizers: Brian J. White & Douglas P. Munoz, Centre for Neuroscience Studies, Queen's University, Kingston, ON, Canada

Presenters: Jared Abrams, Wolfgang Einhäuser, Brian J. White, Michael Dorr, Neil Mennie

Understanding how we perceive and act upon complex natural environments is one of the most pressing challenges in visual neuroscience, with applications that have potential to revolutionize our understanding of the brain, machine vision, and artificial intelligence, to clinical applications such as the detection of visual or mental disorders and neuro-rehabilitation. Until recently, the study of active vision - how visual stimuli give rise to eye movements, and conversely how eye movements influence vision - has largely been restricted to simple stimuli in artificial laboratory settings. Historically, much work on the visual system has been accomplished in this way, but to fully understand vision it is essential to measure behavior under the conditions in which visual systems naturally evolved. This symposium covers some of the latest research on vision and eye movements in natural environments. The talks will explore methods of quantifying natural vision, and compare/contrast behavior across various levels of stimulus complexity and task constraint, from visual search in natural scenes (Abrams, Bradley & Geisler), to unconstrained viewing of natural dynamic video in humans (Dorr, Wallis & Bex), and non-human primates during single-cell recording (White, Itti & Munoz), and real-world gaze behavior using portable eye-tracking (Einhäuser & 't Hart; Mennie, Zulkifli, Mahadzir, Miflah & Babcock). Thus, the symposium should be of interest to a wide audience from visual psychophysicists, to oculomotor neurophysiologists, and cognitive/computational scientists.

Fixation search in natural scenes: a new role for contrast normalization

Speaker: Jared Abrams, Center for Perceptual Systems, University of Texas, Austin, USA

Authors: Chris Bradley, Center for Perceptual Systems, University of Texas, Austin; Wilson S. Geisler, Center for Perceptual Systems, University of Texas, Austin

Visual search is a fundamental behavior, yet little is known about search in natural scenes. Previously, we introduced the ELM (entropy limit minimization) fixation selection rule, which selects fixations that maximally reduce uncertainty about the location of the target. This rule closely approximates the Bayesian optimal decision rule, but is simpler computationally, making the ELM rule a useful benchmark for characterizing human performance. Previously, we found that the ELM rule predicts several aspects of fixation selection in naturalistic (1/f) noise, including the distributions of fixation location, saccade magnitude, and saccade direction. However, the ELM rule is only optimal when the detectability of the target (the visibility map) falls off from the point of fixation in the same way for all potential fixation locations, which holds for backgrounds with relatively constant spatial structure, like statistically stationary 1/f noise. Most natural scenes do not satisfy this assumption; they are highly non-stationary. By combining empirical measurements of target detectability in natural backgrounds with a straight-forward mathematical analysis, we arrive at a generalized ELM rule (nELM rule) that is optimal for non-stationary backgrounds. The nELM searcher divides (normalizes) the current target probability map (posterior-probability map) by the estimated local contrast at each location in the map. It then blurs (convolves) this normalized map with the visibility map for a uniform background. The peak of the blurred map is the optimal location for the next fixation. We will describe the predictions and performance of the nELM searcher.

Eye movements in natural scenes and gaze in the real world

Speaker: Wolfgang Einhäuser, Philipps-University Marburg, Department of Neurophysics, Marburg, Germany

Authors: Bernard Marius 't Hart, Philipps-University Marburg, Department of Neurophysics, Marburg, Germany

In comparisons between item-limit and continuous-resource models of Gaze is widely considered a good proxy for spatial attention. We address whether such "overt attention" is related to other attention measures in natural scenes, and to what extent laboratory results on eye movements transfer to real-world gaze orienting. We find that the probability of a target to be detected in a rapid-serial-visual-presentation task correlates with its probability to be fixated during prolonged viewing, and that both measures are similarly affected by modifications to the target's contrast. This shows a direct link between covert attention in time and overt attention in space for natural stimuli. Especially in the context of computational vision, the probability of an item to be fixated ("salience") is frequently equated with its "importance", the probability of it being recalled during scene description. While we confirm a relation between salience and importance, we dissociate these measures by changing an item's contrast: whereas salience is affected by the actual features, importance is driven by the observer's expectations about these features based on scene statistics. Using a mobile eye-tracking device we demonstrate that eye-tracking experiments in typical laboratory conditions have limited predictive power for real-world gaze orienting. Laboratory data fail to measure the substantial effects of implicit tasks that are imposed on the participant by the environment to avoid severe costs (e.g., tripping over) and typically fail to include the distinct contributions of eye, head and body for orienting gaze. Finally, we provide some examples for applications of mobile gaze-tracking for ergonomic workplace design and aiding medical diagnostics.

Visual coding in the superior colliculus during unconstrained viewing of natural dynamic video

Speaker: Brian J. White, Centre for Neuroscience Studies, Queen's University, Kingston, ON, Canada

Authors: Laurent Itti, Dept of Computer Science, University of Southern California, USA; Douglas P. Munoz, Centre for Neuroscience Studies, Queen's University, Kingston, ON, Canada

The superior colliculus (SC) is a multilayered midbrain structure with visual representations in the superficial-layers (SCs), and sensorimotor representations linked to the control of eye movements/attention in the intermediate-layers (SCi). Although we have extensive knowledge of the SC using simple stimuli, we know little about how the SC behaves during active-vision of complex natural stimuli. We recorded single-units in the monkey SC during unconstrained viewing of natural dynamic video. We used a computational model to predict visual saliency at any retinal location, any point in time. We parsed fixations into tertiles according to the averaged model-predicted saliency value (low, medium, high) in the response field (RF) around the time of fixation (50-400ms post-fixation). The results showed a systematic increase in post-fixation discharge with increasing saliency. We then examined a subset of the total fixations based on the direction of the next saccade (into vs. opposite the RF), under the assumption that saccade direction coarsely indicates the top-down goal of the animal ("value" of the goal-directed stimulus). SCs neurons showed the same enhanced response for greater saliency irrespective of next saccade direction, whereas SCi neurons only showed an enhanced response for greater saliency when the stimulus that evoked it was the goal of the next saccade (was of interest/value). This implies that saliency is controlled closer to the output of the saccade circuit, where priority (combined representation of saliency and relevancy) is presumably signaled and the saccade command is generated. The results support functionally distinct roles of SCs and SCi, whereby the former fit the role of a visual saliency map, and the latter a priority map.

Visual sensitivity under naturalistic viewing conditions

Speaker: Michael Dorr, Schepens Eye Research Institute, Dept of Ophthalmology, Harvard Medical School, and Institute for Neuro- and Bioinformatics, University of Lübeck, Germany

Authors: Thomas S Wallis, Schepens Eye Research Institute, Dept of Ophthalmology, Harvard Medical School, and Centre for Integrative Neuroscience and Department of Computer Science, The University of Tübingen, Tübingen, Germany; Peter J Bex, Schepens Eye Research Institute, Dept of Ophthalmology, Harvard Medical School

Psychophysical experiments typically use very simple stimuli, such as isolated dots and gratings on uniform backgrounds, and allow no or only very stereotyped eye movements. While these viewing conditions are highly controllable, they are not representative of real-world vision, which is characterized by a complex, broadband input and several eye movements per second. We performed a series of experiments in which subjects freely watched high-resolution nature documentaries and TV shows on a gaze-contingent display. Eye-tracking at 1000 Hz and fast video processing routines allowed us to precisely modulate the stimulus in real time and in retinal coordinates. The task then was to locate either bandpass contrast changes or geometric distortions that briefly appeared in one of four locations relative to the fovea every few seconds. We confirm a well-known loss of sensitivity when video modulations took place around the time of eye movements, i.e. around episodes of high-speed retinal motion. However, we found that replicating the same retinal input in a passive condition, where subjects maintained central fixation and the video was shifted on the screen, led to a comparable loss in sensitivity. We conclude that no process of active, extra-retinal suppression is needed to explain peri-saccadic visual sensitivity under naturalistic conditions. We further find that the detection of spatial modifications depends on the spatio-temporal structure of the underlying scene, such that distortions are harder to detect in areas that vary rapidly across space or time. These results highlight the importance of naturalistic assessment for understanding visual processing.

Spatio-Temporal Dynamics of the use of gaze in natural tasks by a Sumatran Orangutan (Pongo abelli)

Speaker: Neil Mennie, University of Nottingham, Malaysia Campus, Malaysia

Authors: Nadia Amirah Zulkifli, University of Nottingham Malaysia Campus; Mazrul Mahadzir, University of Nottingham Malaysia Campus; Ahamed Miflah, University of Nottingham Malaysia Campus; Jason Babcock, Positive Science LLC, New York, USA

Studies have shown that in natural tasks where actions are often programmed sequentially, human vision is an active, task-specific process (Land, et al., 1999; Hayhoe et al., 2003). Vision plays an important role in the supervision of these actions, and knowledge of our surroundings and spatial relationships within the immediate environment is vital for successful task scheduling and coordination of complex action. However, little is known about the use of gaze in natural tasks by great apes. Orangutans usually live high in the canopy of the rainforests of Borneo and Sumatra, where a good spatial knowledge of their immediate surroundings must be important to an animal that has the capability to accurately reach/grasp with four limbs and to move along branches. We trained a 9yr old captive born Sumatran orangutan to wear a portable eye tracker and recorded her use of gaze in a number of different tasks such as locomotion, visual search and tool use in an enclosure at the National Zoo of Malaysia. We found that her gaze was task specific, with different eye movement metrics in different tasks. Secondly we also found that this animal made anticipatory, look-ahead eye movements to future targets (Mennie et al., 2007) when picking up sultanas from a board using her upper limbs. This semi-social animal is likely to be capable of the similar, high-level use of gaze to that of a social species of hominidae - humans.

S2 Beyond the FFA: The role of the ventral anterior temporal lobes in face processing

Friday, May 16, 12:00 - 2:00 pm, Pavilion

Organizers: Jessica Collins & Ingrid Olson, Temple University

Presenters: Winrich Friewald, Stefano Anzellotti, Jessica Collins, Galia Avidan, Stefan Köhler

Extensive research supports the existence of a specialized face-processing network that is distinct from the visual processing areas used for general object recognition. The majority of this work has been aimed at characterizing the response properties of the fusiform face area (FFA) and the occipital face area (OFA), which are thought to constitute the core network of brain regions responsible for facial identification. Recent findings of face-selective cortical regions in more anterior regions of the macaque brainÂ– in the ventral anterior temporal lobe (vATL) and in the orbitofrontal cortex casts doubt on this simple characterization of the face network. This macaque research is supported by fMRI research in humans showing functionally homologous face-processing areas in the vATLs of humans. In addition, there is intracranial EEG and neuropsychology research all pointing towards the critical role of the vATL in some aspect of face processing. The function of the vATL face patches is relatively unexplored and the goal of this symposium is to bring together researchers from a variety of disciplines to address the following question: What is the functional role of the vATLs in face perception and memory and how does it interact with the greater face network? Speakers will present recent findings organized around the following topics: 1) The response properties of the vATL face areas in humans; 2) the response properties of the vATL face area in non-human primates; 3) The connectivity of vATL face areas with the rest of the face-processing network; 4) The role of the vATLs in the face-specific visual processing deficits in prosopagnosia; 5) The sensitivity of the vATLs to conceptual information; and 6) the representational demands that modulate the involvement of the perirhinal cortex in facial recognition. The implications of these findings to theories of face processing and object processing more generally will be discussed.

Face-processing hierarchies in primates

Speaker: Winrich Friewald, The Rockefeller University

The neural mechanisms of face recognition have been extensively studied in both humans and macaque monkeys. Results obtained with similar technologies, chiefly functional brain imaging now allows for detailed cross-species comparisons of face-processing circuitry. A crucial node in this circuit, located at the interface of face perception and individual recognition, is located in the ventral anterior temporal lobe. In macaque monkeys, face selective cells have been found in this region through electrophysiological recordings, a face-selective patch identified with functional magnetic resonance imaging (fMRI), and the unique functional properties of cells within these fMRI-identified regions characterized, suggesting a role in invariant face identification. Furthermore activity in this patch been causally linked, through combinations of electrical microstimulation and psychophysics, to different kinds of face recognition behavior. Not far away from this face selective region, experience-dependent specializations for complex object shapes and their associations have been located, and the mechanisms of these processes studied extensively. In my talk I will present this work on face processing in the ventral anterior temporal lobe of the macaque brain, its relationship to face processing in other face regions and to processes in neighboring regions, its implications for object recognition in general, and the impact of this work for understanding the mechanisms of human face recognition.

Invariant representations of face identity in the ATL

Speaker: Stefano Anzellotti, Harvard University

Authors: Alfonso Caramazza, Harvard University

A large body of evidence has documented the involvement of occipitotemporal regions in face recognition. Neuropsychological studies found that damage to the anterior temporal lobes (ATL) can lead to face recognition deficits, and recent neuroimaging research has shown that the ATL contain regions that respond more strongly to faces than to other categories of objects. What are the different contributions of anterior temporal and occipitotemporal regions to face recognition? In a series of fMRI studies, we investigated representations of individual faces in the human ATL using computer generated face stimuli for which participants did not have individual-specific associated knowledge. Recognition of face identity from different viewpoints and from images of part of the face was tested, using an approach in which pattern classifiers are trained and tested on the responses to different stimuli depicting the same identities. The anterior temporal lobes were found to encode identity information about faces generalizing across changes in the stimuli. Invariant information about face identity was found to be lateralized to the right hemisphere. Some tolerance across image transformations was also detected in occipitotemporal regions, but it was limited to changes in viewpoint, suggesting a process of increasing generalization from posterior to anterior temporal areas. Consistent with this interpretation, information about identity-irrelevant details of the images was found to decline moving along the posterior-anterior axis, and was not detected in the ATL.

The role of the human vATL face patches in familiar face processing

Speaker: Jessica Collins, Temple University

Authors: Ingrid Olson, Temple University

Studies of nonhuman primates have reported the existence of face sensitive patches in the ventral anterior temporal lobes. Using optimized imaging parameters recent fMRI studies have identified a functionally homologous brain region in the ventral anterior temporal lobes (vATLs) of humans. The human vATL shows sensitivity to both perceptual and conceptual features of faces, suggesting that it is involved in some aspects of both face perception and face memory. Supporting a role of the vATLs in face perception, activity patterns in the human vATL face patches discriminate between unfamiliar facial identities, and unilateral damage to the vATLs impairs the ability to make fine-grained discriminations between simultaneously displayed faces when morphed stimuli are used. Supporting a role of the vATLs in face memory, activity in the vATLs is up-regulated for famous faces and for novel faces paired with semantic content. The left ATL appears to be relatively more sensitive to the verbal or semantic aspects of faces, while the right ATL appears to be relatively more sensitive to visual aspects of face, consistent with lateralized processing of language. We will discuss the implications of these findings and propose a revised model of face processing in which the vATLs serve a centralized role in linking face identity to face memory as part of the core visual face-processing network.

Structural and functional impairment of the face processing network in congenital prosopagnosia

Speaker: Galia Avidan, Ben Gurion University

Authors: Michal Tanzer, Ben Gurion University; Marlene Behrmann, Carnegie Mellon University

There is growing consensus that accurate and efficient face recognition is mediated by a neural circuit comprised of a posterior “core” and an anterior “extended” set of regions. In a series of functional and structural imaging studies, we characterize the distributed face network in individuals with congenital prosopagnosia (CP) - a lifelong impairment in face processing - relative to that of matched controls. Interestingly, our results uncover largely normal activation patterns in the posterior core face patches in CP. More recently, we also documented normal activity of the amygdala (emotion processing) as well as normal, or even enhanced functional connectivity between the amygdala and the core regions. Critically, in the same individuals, activation of the anterior temporal cortex, which is thought to mediate identity processing, was reduced and connectivity between this region and the posterior core regions was disrupted. The dissociation between the neural profiles of the anterior temporal lobe and amygdala was evident both during a task-related face scan and during a resting state scan, in the absence of visual stimulation. Taken together, these findings elucidate selective disruptions in neural circuitry in CP, and are also consistent with impaired white matter connectivity to anterior temporal cortex and prefrontal cortex documented in these individuals. These results implicate CP as disconnection syndrome, rather than an alteration localized to a particular brain region. Furthermore, they offer an account for the known behavioral differential difficulty in identity versus emotional expression recognition in many individuals with CP.

Functional role and connectivity of perirhinal cortex in face processing

Speaker: Stefan Köhler, University of Western Ontario

Authors: Ed O'Neil, University of Western Ontario

The prevailing view of medial temporal lobe (MTL) functioning holds that its structures are dedicated to declarative long-term memory. Recent evidence challenges this view, suggesting that perirhinal cortex (PrC), which interfaces the MTL with the ventral visual pathway, supports highly integrated object representations that are critical for perceptual as well as for memory-based discriminations. Here, we review research conducted with fMRI in healthy individuals that addresses the role of PrC, and its functional connectivity, in the context of face processing. Our research shows that (i) PrC exhibits a performance-related involvement in recognition-memory as well as in perceptual oddball judgments for faces; (ii) PrC involvement in perceptual tasks is related to demands for face individuation; (ii) PrC exhibits resting-state connectivity with the FFA and the amygdala that has behavioural relevance for the face-inversion effect; (iii) task demands that distinguish recognition-memory from perceptual-discrimination tasks are reflected in distinct patterns of functional connectivity between PrC and other cortical regions, rather than in differential PrC activity. Together, our findings challenge the view that mnemonic demands are the sole determinant of PrC involvement in face processing, and that its response to such demands uniquely distinguishes its role from that of more posterior ventral visual pathway regions. Instead, our findings point to the importance of considering the nature of representations and functional connectivity in efforts to elucidate the contributions of PrC and other cortical structures to face processing.

S3 Mid-level representations in visual processing

Friday, May 16, 2:30 - 4:30 pm, Talk Room 1

Organizer: Jonathan Peirce, University of Nottingham

Presenters: Jonathan Peirce, Anitha Pasupathy, Zoe Kourtzi, Gunter Loffler, Tim Andrews, Hugh Wilson

A great deal is known about the early stages of visual processing, whereby light of different wavelengths is detected and filtered in such a way as to represent something approximating “edges”. A large number of studies are also examining the “high-level” processing and representation of visual objects; the representation of faces and scenes, and the visual areas responsible for their processing. Remarkably few studies examine either the intervening “mid-level” representations or the visual areas that are involved in this level of processing. This symposium will examine what form these intermediate representations might take, and what methods we have available to study such mechanisms. The speakers have used a variety of methods to try and understand mid-level processing and the associated visual areas. Along the way, a number of questions will be considered. Do we even have intermediate representations; surely higher-order object representations could be built directly on the outputs of V1 cells since all of the information is available there? How does such a representation not fall foul of the problem of parameter explosion? What aspects of the visual scene are encoded at this level? How could we understand such representations further? Why have we not made further progress in this direction before; is the problem simply too hard to study? The symposium is designed for attendees of all levels and will involve a series of 20 minute talks (each including 5 minutes for questions) from each of the speakers. We hope to encourage people that this is an important and tangible problem that vision scientists should be working hard to solve.

Compound feature detectors in mid-level vision

Speaker: Jonathan Peirce, University of Nottingham

A huge number of studies have considered low-level visual processes (such as the detection of edges, colors and motion) and high-level visual processes (such as the processing of faces and scenes). Relatively few studies examine the nature of intermediate visual representations, or "mid-level" vision. One approach to studying mid-level visual representations might be to try and understand the mechanisms that combine the outputs of V1 neurons to create an intermediate feature detector. We have used adaptation techniques to try and probe the existence of detectors for combinations of sinusoids that might form plaid form detectors or curvature detectors. We have shown for both of these features that adaptation effects to the compound has been greater than predicted by adaptation to the parts alone, and that this is greatest when the components form a plaid that we perceive as coherent or a curve that is continuous. To create such representations requires simple logical AND-gates, which might be formed simply by summing the nonlinear outputs of V1 neurons. Many questions remain however, about where in the visual cortex these representations are stored, and how the different levels of representation interact.

Boundary curvature as a basis of shape encoding in macaque area V4

Speaker: Anitha Pasupathy, University of Washington

The broad goal of research in my laboratory is to understand how visual form is encoded in the intermediate stages of the ventral visual pathway, how these representations arise and how they contribute to object recognition behavior. Our current focus is primate V4, an area known to be critical for form processing. Given the enormity of the shape-encoding problem, our strategy has been to test specific hypotheses with custom-designed, parametric, artificial stimuli. With guidance from shape theory, computer-vision and psychophysical literature we identify stimulus features (for example T-junctions) that might be critical in natural vision and work these into our stimulus design so as to progress in a controlled fashion toward more naturalistic stimuli. I will present examples from our past and current experiments that successfully employ this strategy and have led to the discovery of boundary curvature as a basis for shape encoding in area V4. I will conclude with some brief thoughts on how we might move from the highly-controlled stimuli we currently use to the more rich and complex stimuli of natural vision.

Adaptive shape coding in the human visual brain

Speaker: Zoe Kourtzi, University of Birmingham

In the search for neural codes, we typically measure responses to input stimuli alone without considering their context in space (i.e. scene configuration) or time (i.e. temporal history). However, accumulating evidence suggests an adaptive neural code that is dynamically shaped by experience. Here, we present work showing that experience plays a critical role in molding mid-level visual representations and shape perception. Combining behavioral and brain imaging measurements we demonstrate that learning optimizes the binding of local elements into shapes, and the selection of behaviorally relevant features for shape categorization. First, we provide evidence that the brain flexibly exploits image regularities and learns to use discontinuities typically associated with surface boundaries for contour linking and target identification. Specifically, learning of regularities typical in natural contours (i.e., collinearity) can occur simply through frequent exposure, generalize across untrained stimulus features, and shape processing in occipitotemporal regions. In contrast, learning to integrate discontinuities (i.e., elements orthogonal to contour paths) requires task-specific training, is stimulus dependent, and enhances processing in intraparietal regions. Second, by reverse correlating behavioral and fMRI responses with noisy stimulus trials, we identify the critical image parts that determine the observersÂ' choice in a shape categorization task. We demonstrate that learning optimizes shape templates by tuning the representation of informative image parts in higher ventral cortex. In sum, we propose that similar learning mechanisms may mediate long-term optimization through development, tune the visual system to fundamental principles of feature binding, and shape visual category representations.

Probing intermediate stages of shape processing

Speaker: Gunter Loffler, Glasgow Caledonian University

The visual system provides a representation of what and where objects are. This entails parsing the visual scene into distinct objects. Initially, the visual system encodes information locally. While interactions between adjacent cells can explain how local fragments of an objectÂ's contour are extracted from a scene, more global mechanisms have to be able to integrate information beyond that of neighbouring cells to allow for the representation of extended objects. This talk will examine the nature of intermediate-level computations in the transformation from discrete local sampling to the representation of complex objects. Several paradigms were invoked to study how information concerning the position and orientation of local signals is combined: a shape discrimination task requiring observers to discriminate between contours; a shape coherence task measuring the number of elements required to detect a contour; a shape illusion in which positional and orientational information is combined inappropriately. Results support the notion of mechanisms that integrate information beyond that of neighbouring cells and are optimally tuned to a range of different contour shapes. Global integration is not restricted to central vision: peripheral data show that certain aspects of this process only emerge at intermediate stages. Moreover, intermediate processing appears vulnerable to damage. Diverse clinical populations (migraineurs, pre-term children and children with Cortical Visual Impairment) show specific deficits for these tasks that cannot be accounted for by low-level processes. Taken together, evidence is converging towards the identification of an intermediate level of processing, at which sensitivity to global shape attributes emerges.

Low-level image properties of visual objects explain category-selective patterns of neural response across the ventral visual pathway

Speaker: Ronen Segev, Ben Gurion University of the Negev, Department of Life Sciences and Zlotowski Center for Neuroscience

Neuroimaging research over the past 20 years has begun to reveal a picture of how the human visual system is organized. A key organizing principle that has arisen from these studies is the distinction between low-level and high-level visual regions. Low-level regions are organized into visual field maps that are tightly linked to the image properties of the stimulus. In contrast, high-level visual areas are thought to be arranged in modules that are selective for particular object categories. It is unknown, however, whether this selectivity is truly based on object category, or whether it reflects tuning for low-level features that are common to images from a particular category. To address this issue, we compared the pattern of neural response elicited by each object category with the corresponding low-level properties of images from each object category. We found a strong positive correlation between the neural patterns and the underlying low-level image properties. Importantly, the correlation was still evident when the within-category correlations were removed from the analysis. Next, we asked whether low-level image properties could also explain variation in the pattern of response to exemplars from individual object categories (faces or scenes). Again, a positive correlation was evident between the similarity in the pattern of neural response and the low-level image properties of exemplars from individual object categories. These results suggest that the pattern of response in high-level visual areas may be better explained by the image statistics of visual stimuli than by their associated categorical or semantic properties.

From Orientations to Objects: Configural Processing in the Ventral Stream

Speaker: Hugh Wilson, York University

I shall review psychophysical and fMRI evidence for a hierarchy of intermediate processing stages in the ventral or form vision system. A review of receptive field sizes from V1 up to TE indicates an increase in diameter by a factor of about 3.0 from area to area. This is consistent with configural combination of adjacent orientations to form curves or angles, followed by combination of curves and angles to form descriptors of object shapes. Psychophysical and fMRI evidence support this hypothesis, and neural models provide a plausible explanation of this hierarchical configural processing.

S4 The visual white-matter matters! Innovation, data, methods and applications of diffusion MRI and fiber tractography

Friday, May 16, 2:30 - 4:30 pm, Pavilion

Organizers: Franco Pestilli & Ariel Rokem, Stanford University

Presenters: Ariel Rokem, Andrew Bock, Holly Bridge, Suzy Scherf, Hiromasa Takemura, David Van Essen

For about two decades, functional MR imaging has allowed investigators to map visual cortex in the living human brain. Vision scientists have identified clusters of cortical regions with different functional properties. The function of these maps is determined by both the selectivity of their neurons, as well as their connections. Communication between cortical regions is carried by long-range white-matter fascicles. The wiring of these fascicles is important for implementing the perceptual functions of the visual maps in the occipital, temporal and parietal cortex. Magnetic resonance diffusion imaging (dMRI) and computational tractography are the only technologies that enable scientists to measure the white matter in the living human brain. In the decade since their development, these technologies revolutionized our understanding of the importance of human white-matter for health and disease. Recent advances in dMRI and fiber tractography have opened new avenues of understanding the white-matter connections in the living human brain. With the advent of these technologies we are for the first time in a position to draw a complete wiring diagram of the human visual system. By probing the motion of water molecules at the micron scale, dMRI can be used to study the microstructural properties and geometric organization of the visual white-matter fascicles. These measurements in living brains can help clarify the relationship between the properties of the tissue within the fascicles and visual perception, both in healthy individuals and in cases where vision is impeded through disease. Prior to these measurements, the white matter was thought of as a passive cabling system. But modern measurements show that white matter axons and glia respond to experience and that the tissue properties of the white matter are transformed during development and following training. The white matter pathways comprise a set of active wires and the responses and properties of these wires predict human cognitive and perceptual abilities. This symposium targets a wide range of investigators working in vision science by providing an introduction to the principles of dMRI measurements, algorithms used to identify anatomical connections and models used to characterize white-matter properties. The speakers have pioneered the use of diffusion and functional MRI and fiber tractography to study the human visual white-matter in answering a wide range of scientific questions: connectivity, development, plasticity. The symposium will also introduce publicly available resources (analysis software and data) to help advance the study of the human visual cortex and white-matter, with special emphasis on the high-quality MR measurements provided by the Human Connectome Project (HCP).

Measuring and modelling of diffusion and white-matter tracts

Speaker: Ariel Rokem, Stanford University

Authors: Franco Pestilli

This talk will present a general methodological overview of diffusion MRI (dMRI), with a special focus on methods used to image connectivity and tissue properties in the human visual system. We will start by describing the principles of dMRI measurements. We will then provide an overview of models that are used to describe the signal and make inferences about the properties of the tissue and the trajectories of fiber fascicles in white-matter. We will focus on the classical Diffusion Tensor Model (DTM), which is used in many applications, and on the more recent development of Sparse Fascicle Models (SFM), which are more realistic representations of the signal as a combination of signals from different fascicles. Using cross-validation, we have found that DTM provides an accurate representation of the data, better than the reliability of a repeated measurement. SFM provide even more accurate models of the data, and particularly in regions where different fiber tracts cross. In the second part of the talk, we will focus on tractography. With special emphasis on probabilistic and deterministic tractography. We will introduce ideas about validation of white-matter trajectories and to perform statistical inferences about connectivity between different parts of the visual system. A major problem of the field is that different algorithms provide different estimates of connectivity. This problem is solved by choosing the fiber estimates that best account for the data in a repeated measurement (cross-validation).

Gross topographic organization in the corpus callosum is preserved despite abnormal visual input

Speaker: Andrew Bock, University of Washington

Authors: Melissa Saenz, University of Laussane; Holly Bridge, Oxford; Ione Fine, University of Washington

The loss of sensory input early in development has been shown to induce dramatic anatomical and functional changes within the central nervous system. Using probabilistic diffusion tractography, we examined the retinotopic organization of splenial callosal connections within early blind, anophthalmic, achiasmatic and control subjects. Early blind subjects experience prenatal retinal “waves” of spontaneous activity similar to those of sighted subjects, and only lack postnatal visual experience. In anophthalmia, the eye is either absent or arrested at an early prenatal stage, depriving these subjects of both pre- and postnatal visual input, while in achiasma there is a lack of crossing at the optic chiasm such that the white matter projection from each eye is ipsilateral. Comparing these groups provides a way of separating the influence of pre- and postnatal retinal deprivation and abnormal visual input on the organization of visual connections across hemispheres. We found that retinotopic mapping within the splenium was not measurably disrupted in any of these groups compared to visually normal controls. These results suggest that neither prenatal retinal activity nor postnatal visual experience plays a role in the large-scale topographic organization of visual callosal connections within the splenium, and the general method we describe provides a useful way of quantifying the organization of large white matter tracts.

Using diffusion-weighted tractography to investigate dysfunction of the visual system

Speaker: Holly Bridge, Oxford

Authors: Rebecca Millington; James Little; Kate Watkins

The functional consequences of damage to, or dysfunction of, different parts of the visual pathway have been well characterized for many years. Possibly the most extreme dysfunction is the lack of eyes (anophthalmia) which prevents any stimulation of this pathway by light input. In this case, functional MRI indicates the use of the occipital cortex for processing of language, and other auditory stimuli. This raises the question of how this information gets to the occipital cortex; are there differences in the underlying anatomical connectivity or can existing pathways be used to carry different information? Here I’ll describe several approaches we have taken to try to understand the white matter connectivity in anophthalmia using diffusion tractography. Damage to the visual pathway can also be sustained later in life, either to the periphery or to the post-chiasmatic pathway (optic tract, lateral geniculate nucleus, optic radiation or visual cortex). When damage occurs in adulthood, any changes to white matter are likely to be the result of degeneration. Sensitive measures of white matter integrity can be used to illustrate patterns of degeneration in patient populations. However, it is also the case that in the presence of lesions, and where white matter tracts are relatively small (e.g. optic tract) measures derived from diffusion-weighted imaging can be misleading. In summary I will present an overview of the potential for employing diffusion tractography to understand plasticity and degeneration in the abnormal visual system, highlighting potential confounds that may arise in patient populations.

Structural properties of white matter circuits necessary for face perception

Speaker: Suzy Scherf, Penn State

Authors: Marlene Behrmann, Carnegie Mellon University; Cibu Thomas, NIH; Galia Avidan, Beer Sheva University; Dan Elbich, Penn State University

White matter tracts, which communicate signals between cortical regions, reportedly play a critical role in the implementation of perceptual functions. We examine this claim by evaluating structural connectivity, and its relationship to neural function, in the domain of face recognition in both developing individuals and those with face recognition deficits. In all studies, we derived the micro- as well as macro-structural properties of the inferior longitudinal fasciculus (ILF) and of the inferior fronto-occipital fasciculus (IFOF), which connect distal regions of cortex that respond preferentially to faces. In participants aged 6-23 years old, we observed age-related differences in both the macro- and micro-structural properties of the ILF. Critically, these differences were specifically related to an age-related increase in the size of the functionally defined fusiform face area. We then demonstrated the causal nature of the structure-function relationship in individuals who are congenitally prosopagnosic (CP) and in an aging population (who exhibits an age-related decrement in face recognition). The CPs exhibited reduced volume of the IFOF and ILF, which was related to the severity of their face processing deficit. Similarly, in the older population there were also significant reductions in the structural properties of the ILF and IFOF that were related to their behavioral performance. Finally, we are exploring whether individual differences in face-processing behavior of normal adults are related to variations in these structure-function relations. This dynamic association between emerging structural connectivity, functional architecture and perceptual behavior reveals the critical role of neural circuits in human cortex and perception.

A major white-matter wiring between the ventral and dorsal stream

Speaker: Hiromasa Takemura, Stanford University

Authors: Brian Wandell

Over the last several decades, visual neuroscientists have learned how to use fMRI to identify multiple visual field maps in the living human brain. Several theories have been proposed to characterize the organization of these visual field maps, and a key theory with substantial support distinguishes dorsal stream involving with spatial processing and ventral stream involving categorical processing. We combined fMRI, diffusion MRI and fiber tractography to identify a major white matter pathway, the Vertical Occipital Fasciculus (VOF), connecting maps within the dorsal and ventral visual streams. We use a model-based method, LInear Fascicle Evaluation (LIFE), to assess the statistical evidence supporting the VOF wiring pattern. There is strong evidence supporting the hypothesis that dorsal and ventral streams of visual maps communicate through the VOF. This pathway is large and its organization suggests that the human ventral and dorsal visual maps communicate substantial information through V3A/B and hV4/VO-1. We suggest that the VOF is crucial for transmitting signals between regions that encode object properties including form, identity and color information and regions that map spatial location to action plans. Findings on the VOF will extend the current understandings of the human visual field map hierarchy.

What is the Human Connectome Project telling us about human visual cortex?

Speaker: David Van Essen, Washington University

The Human Connectome Project (HCP) is acquiring and sharing vast amounts of neuroimaging data from healthy young adults, using high-resolution structural MRI, diffusion MRI, resting-state fMRI, and task-fMRI. Together, these complementary modalities provide invaluable information and insights regarding the organization and connectivity of human visual cortex. This presentation will highlight recent results obtained using surface-based analysis and visualization approaches to characterize structural and functional connectivity of visual cortex in individuals and group averages.

S5 What are you doing? Recent advances in visual action recognition research

Friday, May 16, 5:00 - 7:00 pm, Talk Room 1

Organizers: Stephan de la Rosa & Heinrich Bülthoff, Max Planck Institute for Biological Cybernetics

Presenters: Nick Barraclough, Cristina Becchio, Stephan de la Rosa, Ehud Zohary, Martin. A. Giese

The visual recognition of actions is critical for humans when interacting with their physical and social environment. The unraveling of the underlying processes has sparked wide interest in several fields including computational modeling, neuroscience, and psychology. Recent research endeavors on how people recognize actions provide important insights into the mechanisms underlying action recognition. Moreover, they give new ideas for man-machine interfaces and have implications for artificial intelligence. The aim of the symposium is to provide an integrative view on recent advances in our understanding of the psychological and neural processes underlying action recognition. Speakers will discuss new and related developments in the recognition of mainly object- and human-directed actions from a behavioral, neuroscientific, and modeling perspective. These developments include, among other things, a shift from the investigation of isolated actions to the examination of action recognition under more naturalistic conditions including contextual factors and the human ability to read social intentions from the recognized actions. These findings are complemented by neuroscientific work examining the action representation in motor cortex. Finally, a novel theory of goal-directed actions will be presented that integrates the results from various action recognition experiments. The symposium will first discuss behavioral and neuroscientific aspects of action recognition and then will shift its attention to the modeling of the processes underlying action recognition. More specifically, Nick Barraclough will present research on action recognition using adaptation paradigms and object-directed and locomotive actions. He will talk about the influence of the observer's mental state on action recognition using displays that present the action as naturalistic as possible. Cristina Becchio will talk about actions and their ability to convey social intentions. She will present research on the translation of social intentions into kinematic patterns of two interacting persons and discuss the observers' ability to visually use these kinematic cues for inferring social intentions. Stephan de la Rosa will focus on social actions and talk about the influence of social and temporal context on the recognition of social actions. Moreover, he will present research on the visual representation underlying the recognition of social interactions. Ehud Zohary will discuss the representation of actions within the motor pathway using fMRI and the sensitivity of the motor pathway to visual and motor aspects of an action. Martin Giese will wrap up the symposium by presenting a physiologically plausible neural theory for the perception of goal-directed hand actions and discuss this theory in the light of recent physiological findings. The symposium is targeted towards the general VSS audience and provides an comprehensive and integrative view about an essential ability of human visual functioning.

Other peoples' actions interact within our visual system

Speaker: Nick Barraclough, Department of Psychology, University of York, York, UK

Perception of actions relies on the behavior of neurons in the temporal cortex that respond selectively to the actions of other individuals. It is becoming increasingly clear that visual adaptation, well known for influencing early visual processing of more simple stimuli, appears also to have an influence at later processing stages where actions are coded. In a series of studies we, and others, have been using visual adaptation techniques to attempt to characterize the mechanisms underlying our ability to recognize and interpret information from actions. Action adaptation generates action aftereffects where perception of subsequent actions is biased; they show many of the characteristics of both low-level and high-level face aftereffects, increasing logarithmically with duration of action observation, and declining logarithmically over time. I will discuss recent studies where we have investigated the implications for action adaptation in naturalistic social environments. We used high-definition, orthostereoscopic presentation of life-sized photorealistic actors on a 5.3 x 2.4 m screen in order to maximize immersion in a Virtual Reality environment. We find that action recognition and judgments we make about the internal mental state of other individuals is changed in a way that can be explained by action adaptation. Our ability to recognize and interpret the actions of an individual is dependent, not only on what that individual is doing, but the effect that other individuals in the environment have on our current brain state. Whether or not two individuals are actually interacting in the environment, it seems they interact within our visual system.

On seeing intentions in others' movements

Speaker: Cristina Becchio, Centre for Cognitive Science, Department of Psychology, University of Torino, Torino, Italy; Department of Robotics, Brain, and Cognitive Science, Italian Institute of Technology, Genova, Italy

Starting from Descartes, philosophers, psychologists, and more recently neuroscientists, have often emphasized the idea that intentions are not things that can be seen. They are mental states and perception cannot be smart enough to reach the mental states that are hidden away (imperceptible) in the other personÂ's mind. Based on this assumption, standard theories of social cognition have mainly focused the contribution of higher-level cognition to intention understanding. Only recently, it has been recognized that intentions are deeply rooted in the actions of interacting agents. In this talk, I present findings from a new line of research showing that intentions translate into differential kinematic patterns. Observers are especially attuned to kinematic information and can use early differences in visual kinematics to anticipate what another person will do next. This ability is crucial not only for interpreting the actions of individual agents, but also to predict how, in the context of a social interaction between two agents, the actions of one agent relate to the actions of a second agent.

The influence of context on the visual recognition of social actions

Speaker: Stephan de la Rosa, Department Human Perception, Cognition and Action; Max Planck Institute for Biological Cybernetics, Tübingen, Germany

Authors: Stephan Streuber, Department Human Perception, Cognition and Action; Max Planck Institute for Biological Cybernetics, Tübingen, Germany Heinrich Bülthoff, Department Human Perception, Cognition and Action; Max Planck Institute for Biological Cybernetics, Tübingen, Germany

Actions do not occur out of the blue. Rather, they are often a part of human interactions and are, therefore, embedded in an action sequence. Previous research on visual action recognition has primarily focused on elucidating the perceptual and cognitive mechanisms in the recognition of individual actions. Surprisingly, the social and temporal context, in which actions are embedded, has received little attention. I will present studies examining the importance of context on action recognition. Specifically, we examined the influence of social context (i.e. competitive vs. cooperative interaction settings) on the observation of actions during real life interactions and found that social context modulates action observation. Moreover, we investigated the perceptual and temporal factors (i.e. action context as provided by visual information about preceding actions) on action recognition using an adaptation paradigm. Our results provide evidence that experimental effects are modulated by temporal context. These results in the way that action recognition is not guided by the immediate visual information but also by temporal and social contexts.

On the representation of viewed action in the human motor pathways

Speaker: Ehud Zohary, Department of Neurobiology, Alexander Silberman Institute of Life Sciences, Hebrew University of Jerusalem, Israel

I will present our research on the functional properties of brain structures which are involved in object-directed actions. Specifically, we explore the nature of viewed-action representation using functional magnetic resonance imaging (fMRI). One cortical region involved in action recognition is anterior intraparietal (AIP) cortex. The principal factor determining the response in AIP is the identity of the observed hand. Similar to classical motor areas, AIP displays clear preference for the contralateral hand, during motor action (i.e., object manipulation) without visual feedback. This dual visuomotor grasping representation suggests that AIP may be involved in the specific motor simulation of hand actions. Furthermore, viewing object-directed actions (from an egocentric-viewpoint, as in self action) elicits a similar selectivity for the contralateral hand. However, if the viewed action is seen from an allocentric viewpoint (i.e. being performed by another person facing the viewer), greater activation in AIP is found for the ipsilateral hand. Such a mapping may be useful for imitation of hand action (e.g. finger tapping) made by someone facing us which is more accurate when using the opposite (mirror-image) hand. Finally, using the standard "center-out" task requiring visually guided hand movements in various directions, we show that primary motor cortex (M1) is sensitive to both motor and visual components of the task. Interestingly, the visual aspects of movement are encoded in M1 only when they are coupled with motor consequences. Together, these studies indicate that both perceptual and motor aspects are encoded in the patterns of activity in the cortical motor pathways.

Neural theory for the visual perception of goal-directed actions and perceptual causality

Speaker: Martin. A. Giese, Section for Computational Sensomotorics, Dept. for Cognitive Neurology, HIH and CIN, University Clinic Tübingen, Germany

Authors: Falk Fleischer[1,2], Vittorio Caggiano[2,3], Jörn Pomper[2], Peter Thier[2]; [1]Section for Computational Sensomotorics, [2]Dept. for Cognitive Neurology, HIH and CIN, University Clinic Tübingen, Germany, [3]McGovern Institute for Brain Research, M.I.T., Cambridge, MA Supported by the DFG, BMBF, and EU FP7 projects AMARSI, ABC, and the Human Brain Project

The visual recognition of goal-directed movements even from impoverished stimuli, is a central visual function with high importance for survival and motor learning. In cognitive neuroscience and brain imaging a number of speculative theories have been proposed that suggest possible computational processes that might underlie this function. However, these theories typically leave it completely open how the proposed functions might be implemented by local cortical circuits. Complementing these approaches, we present a physiologically-inspired neural theory for the visual processing of goal-directed actions, which provides a unifying account for existing neurophysiological results on the visual recognition of hand actions in monkey cortex. The theory motivated, and partly correctly predicted specific computational properties of action-selective neurons in monkey cortex, which later could be verified physiologically. Opposed to several dominant theories in the field, the model demonstrates that robust view-invariant action recognition from monocular videos can be accomplished without a reconstruction of the three-dimensional structure of the effector, or a critical importance of an internal simulation of motor programs. As a 'side-effect', the model also reproduces simple forms of causality perception, predicting that these stimuli might be processed by similar neural structures as natural hand actions. Consistent with this prediction, F5 mirror neurons can be shown to respond selectively to such stimuli. This suggests that the processing of goal-directed actions might be accounted for by relatively simple neural mechanisms that are accessible by electrophysiological experimentation.

S6 Understanding representation in visual cortex: why are there so many approaches and which is best?

Friday, May 16, 5:00 - 7:00 pm, Pavilion

Organizers: Thomas Naselaris & Kendrick Kay, Department of Neurosciences, Medical University of South Carolina & Department of Psychology, Washington University in St. Louis

Presenters: Thomas Naselaris, Marcel van Gerven, Kendrick Kay, Jeremy Freeman, Nikolaus Kriegeskorte, James J. DiCarlo, MD, PhD

Central to visual neuroscience is the problem of representation: what features of the visual world drive activity in different areas of the visual system? Receptive fields and tuning functions have long served as the basic descriptive elements used to characterize visual representations. In recent years, the receptive field and the tuning function have been generalized and in some cases replaced with alternative methods for characterizing visual representation. These include decoding and multivariate pattern analysis, representational similarity analysis, the use of abstract semantic spaces, and models of stimulus statistics. Given the diversity of approaches, it is important to consider whether these approaches are simply pragmatic, driven by the nature of the data being collected, or whether these approaches might represent fundamentally new ways of characterizing visual representations. In this symposium, invitees will present recent discoveries in visual representation, explaining the generality of their approach and how it might be applicable to future studies. Invitees are encouraged to discuss the theoretical underpinnings of their approach and its criterion for "success". Invitees are also encouraged to provide practical pointers, e.g. regarding stimulus selection, experimental design, and data analysis. Through this forum we hope to move towards an integrative approach that can be shared across experimental paradigms. Audience: This symposium will appeal to researchers interested in computational approaches to understanding the visual system. The symposium is expected to draw interest from a broad range of experimental backgrounds (e.g. fMRI, EEG, ECoG, electrophysiology). Invitees: The invitees will consist of investigators who have conducted pioneering work in computational approaches to studying visual representation.

Visual representation in the absence of retinal input

Speaker: Thomas Naselaris, Department of Neurosciences, Medical University of South Carolina, Charleston, SC

An important discovery of the last two decades is that receptive fields in early visual cortex provide an efficient basis for generating images that have the statistical structure of natural scenes. This discovery has lent impetus to the theory that receptive fields in early visual cortex can function not only as passive filters of retinal input, but as mechanisms for generating accurate representations of the visual environment that are independent of retinal input. A number of theoretical studies argued that such internal visual representations could play an important functional role in vision by supporting probabilistic inference. In this talk, we will explore the idea of receptive fields as generators of internal representations by examining the role that receptive fields play in generating mental images. Mental images are the canonical form of internal visual representation: they are independent of retinal input and appear to be essential for many forms of inference. We present evidence from fMRI studies that voxel-wise receptive field models of the tuning to retinotopic location, orientation, and spatial frequency can account for much of the BOLD response in early visual cortex to imagining previously memorized works of art. We will discuss the implications of this finding for the structure of functional feedback projections to early visual cortex, and for the development of brain-machine interfaces that are driven by mental imagery.

Learning and comparison of visual feature representations?

Speaker: Marcel van Gerven, Donders Institute for Brain, Cognition and Behaviour

Recent developments on the encoding and decoding of visual stimuli have relied on different feature representations such as pixel-level, Gabor wavelet or semantic representations. In previous work, we showed that high-quality reconstructions of images can be obtained via the analytical inversion of regularized linear models operating on individual pixels. However, such simple models do not account for the complex nonlinear transformations of sensory input that take place in the visual hierarchy. I will argue that these nonlinear transformations can be estimated independent of brain data using statistical approaches. Decoding based on the resulting feature space is shown to yield better results than those obtained using a hand-designed feature space based on Gabor wavelets. I will discuss how alternative feature spaces that are either learned or hand-designed can be compared with one another, thereby providing insight into what visual information is represented where in the brain. Finally, I will present some recent encoding and decoding results obtained using ultra-high field MRI.

Identifying the nonlinearities used in extrastriate cortex

Speaker: Kendrick Kay, Department of Psychology, Washington University in St. Louis

In this talk, I will discuss recent work in which I used fMRI measurements to develop models of how images are represented in human visual cortex. These models consist of specific linear and nonlinear computations and predict BOLD responses to a wide range of stimuli. The results highlight the importance of certain nonlinearities (e.g. compressive spatial summation, second-order contrast) in explaining responses in extrastriate areas. I will describe important choices made in the development of the approach regarding stimulus design, experimental design, and analysis. Furthermore, I will emphasize (and show through examples) that understanding representation requires a dual focus on abstraction and specificity. To grasp complex systems, it is necessary to develop computational concepts, language, and intuition that can be applied independently of data (abstraction). On the other hand, a model risks irrelevance unless it is carefully quantified, implemented, and systematically validated on experimental data (specificity).

Carving up the ventral stream with controlled naturalistic stimuli

Speaker: Jeremy Freeman, HHMI Janelia Farm Research Campus

Authors: Corey M. Ziemba, J. Anthony Movshon, Eero P. Simoncelli, and David J. Heeger Center for Neural Science New York University, New York, NY

The visual areas of the primate cerebral cortex provide distinct representations of the visual world, each with a distinct function and topographic representation. Neurons in primary visual cortex respond selectively to orientation and spatial frequency, whereas neurons in inferotemporal and lateral occipital areas respond selectively to complex objects. But the areas in between, in particular V2 and V4, have been more difficult to differentiate on functional grounds. Bottom-up receptive field mapping is ineffective because these neurons respond poorly to artificial stimuli, and top-down approaches that employ the selection of “interesting” stimuli suffer from the curse of dimensionality and the arbitrariness of the stimulus ensemble. I will describe an alternative approach, in which we use the statistics of natural texture images and computational principles of hierarchical coding to generate controlled, but naturalistic stimuli, and then use these images as targeted experimental stimuli in electrophysiological and fMRI experiments. Responses to such “naturalistic” stimuli reliably differentiate neurons in area V2 from those in V1, in both single-units recorded from macaque monkey, and in humans as measured using fMRI. In humans, responses to these stimuli, alongside responses to both simpler and more complex stimuli, suggest a simple functional account of the visual cortical cascade: Whereas V1 encodes basic spectral properties, V2, V3, and to some extent V4 represent the higher-order statistics of textures. Downstream areas capture the kinds of global structures that are unique to images of natural scenes and objects.

Vision as transformation of representational geometry

Speaker: Nikolaus Kriegeskorte, Medical Research Council, Cognition and Brain Sciences Unit, Cambridge, UK

Vision can be understood as the transformation of representational geometry from one visual area to the next, and across time, as recurrent dynamics converge within a single area. The geometry of a representation can be usefully characterized by a representational distance matrix computed by comparing the patterns of brain activity elicited a set of visual stimuli. This approach enables to compare representations between brain areas, between different latencies after stimulus onset, between different individuals and between brains and computational models. I will present results from human functional imaging of early and ventral-stream visual representations. Results from fMRI suggest that the early visual image representation is transformed into an object representation that emphasizes behaviorally important categorical divisions more strongly than accounted for by visual-feature computational models that are not explicitly optimized to distinguish categories. The categorical clusters appear to be consistent across individual human brains. However, the continuous representational space is unique to each individual and predicts individual idiosyncrasies in object similarity judgements. The representation flexibly emphasizes task-relevant category divisions through subtle distortions of the representational geometry. MEG results further suggest that the categorical divisions emerge dynamically, with the latency of categoricality peaks suggesting a role for recurrent processing.

Modern population approaches for discovering neural representations and for discriminating among algorithms that might produce those representations

Speaker: James J. DiCarlo, MD, PhD, Professor of Neuroscience Head, Department of Brain and Cognitive Sciences Investigator, McGovern Institute for Brain Research Massachusetts Institute of Technology, Cambridge, USA

Authors: Ha Hong and Daniel Yamins Department of Brain and Cognitive Sciences and McGovern Institute for Brain Research Massachusetts Institute of Technology, Cambridge, USA

Visual object recognition (OR) is a central problem in systems neuroscience, human psychophysics, and computer vision. The primate ventral stream, which culminates in inferior temporal cortex (IT), is an instantiation of a powerful OR system. To understand this system, our approach is to first drive a wedge into the problem by finding the specific patterns of neuronal activity (a.k.a. neural “representations”) that quantitatively express the brainÂ´s solution to OR. I will argue that, to claim discovery of a neural “representation” for OR, one must show that a proposed population of visual neurons can perfectly predict psychophysical phenomena pertaining to OR. Using simple decoder tools, we have achieved exactly this result, demonstrating that IT representations (as opposed to V4 representations) indeed predict OR phenomena. Moreover, we can "invert" the decoder approach to use large-scale psychophysical measurements to make new, testable predictions about the IT representation. While decoding methods are powerful for exploring the link between neural activity and behavior, they are less well suited for addressing how pixel representations (i.e. images) are transformed into neural representations that subserve OR. To address this issue, we have adopted the representational dissimilarity matrices (RDM) approach promoted by Niko Kriegeskorte. We have recently discovered novel models (i.e. image-computable visual features) that, using the RDM measure of success, explain IT representations dramatically better than all previous models.

Saturday Morning Talks

Perception and action: Locomotion

Saturday, May 17, 8:15 - 9:45 am
Talk Session, Talk Room 1
Moderator: Brett Fajen

21.11, *8:15 am* **Influence of optic flow on the control of walking toward a goal** Li Li[1](lili@hku.hk), Diederick Niehorster[1], William Warren[2], Benjamin Bolte[3], Phil Wieland[3], Markus Lappe[3]; [1]Department of Psychology, The University of Hong Kong, Hong Kong SAR, [2]Department of Cognitive, Linguistic, and Psychological Sciences, Brown University, USA, [3]Institute for Psychology, University of Munster, Germany

Although previous studies have shown that optic flow is used to control human walking, the relative effectiveness of various types of optic flow information and whether humans use their perceived visual heading to control walking toward a goal remain in question. Here we systematically varied optic flow information in the display and examined how it affected walking in an immersive virtual environment as well as passive heading perception. In the walking experiment, participants walked toward a target placed in front of them at 7 m in a virtual environment viewed through a head-mounted display (47°Hx38°V). We varied optic flow information in the display to examine the effects of target motion relative to the observer, sparse flow, expansion, and dense flow on the control of walking toward a goal. The visual heading was displaced ±10° from participants' physical walking direction, thus participants would walk on a curved path toward the target with mean heading error at 10° if they ignored optic flow and walked toward the target egocentric direction. In the parallel heading perception experiment, the displays matched those in the walking experiment, and participants used a mouse to move a probe to their perceived heading at the end of each 2-s trial. Participants walked on the least curved path toward the target when the display contained dense flow. Sparse flow resulted in higher curvature, independent of the expansion cue. Target motion relative to the observer affected walking only at close distances. The mean heading error data of walking are similar to the accuracy and precision data of heading perception. We conclude that visual heading defined by optic flow is used to guide walking toward a goal. The relative effectiveness of optic flow and target egocentric direction is due to the specificity of the information, not an internal cue weighting.

21.12, *8:30 am* **Homing with audio landmarks and path integration** Norbert Boeddeker[1](norbert.boeddeker@uni-bielefeld.de), Alessandro Moscatelli[1], Marc Ernst[1]; [1]Cognitive Neuroscience Department and CITEC, Bielefeld University

Humans use a multitude of cues to orient themselves in space. For homing in unknown terrain it is fundamental to keep track of the starting position and of one's position and orientation relative to this home location. This is commonly referred to as spatial updating. When space is explored by walking around, our senses work together by providing signals for this fundamental ability (e.g. from visual or auditory landmarks) and also locomotion provides a rich amount of information, involving kinesthetic signals and efference copies from the motor system for path integration. How do humans integrate different signals into a coherent representation of space? Here we tested 6 blindfolded participants in a triangle completion task. In a sports hall (size: 25x45m) participants were guided either on the first two legs of a triangular path or transported on a wheel chair to the release position on an indirect, strongly meandering path (5-10x longer than the path home). The participant was instructed to walk a straight line back to the starting position, which sometimes was tagged by an auditory landmark. The task was repeated with different kinds of information available: path integration only (walking, no audio cues), audio landmark only (the participant is passively transported and walks back home using audio landmark cues only), or both (blindfolded walking with audio cues). We find that humans can use either source of spatial information alone for homing, with audio landmarks allowing a higher homing precision than path integration. When both sources are available, the multimodal estimate is a weighted sum of the different unimodal estimates, with the weight of each sensory modality proportional to its precision. These results suggest that humans can estimate the precision of each sensory source of information and combine the sensory signals in a statistically optimal fashion.

21.13, *8:45 am* **The critical period for the visual control of foot placement in complex terrain occurs in the preceding step** Jonathan Matthis[1](matthj5@rpi.edu), Sean Barton[1], Brett Fajen[1]; [1]Cognitive Science Department, Rensselaer Polytechnic Institute

Successful locomotion over complex terrain such as a rocky trail requires walkers to place each step on a safe foothold with high spatiotemporal precision while also taking the future terrain into account. Matthis & Fajen (2013) demonstrated that two step lengths of visual look ahead is sufficient for humans to walk over complex terrain while exploiting the inverted-pendulum-like structure of bipedal gait as efficiently as they do with unrestricted vision. In a follow-up study, we showed that the accuracy of stepping onto a target was unaffected when the target became invisible at any point during the step to that target, but sharply declined when the target disappeared during the preceding step. Taken together, these findings suggest that there is a critical period for the visual control of the placement of each step that occurs during the preceding step. Here we present a study that tests this critical period hypothesis by examining subjects as they walk over a series of irregularly spaced virtual targets projected onto the floor by a LCD projector. Targets were only visible during specific phases of the gait cycle leading up to each target. Indeed, we found that there was a narrow window during the stance phase preceding the step to each target during which the target needed to be visible in order for subjects to accurately place each foot. Even a brief presentation of a target during this critical period yielded better performance than a longer presentation at a different phase of gait. Interestingly, stepping was marginally more accurate when targets were visible for longer than the predicted critical period, regardless of whether they appeared slightly sooner or disappeared slightly later. Given the increased difficulty of the experimental task, this result suggests that subjects' performance was affected by attentional factors in addition to biomechanical constraints.

Acknowledgement: NIH 1R01EY019317

21.14, *9:00 am* **Multi-Agent Simulation of Collective Behavior in Human Crowds** William Warren[1](Bill_Warren@brown.edu), Stéphane Bonneaud[1]; [1]Dept. of Cognitive, Linguistic and Psychological Sciences, Brown University

The collective behavior of human crowds is thought to emerge from local interactions between pedestrians. There are many models of such "flocking" behavior in animals and humans, but few of them are based on experimental evidence about these visually-guided interactions. We have built an empirically-grounded pedestrian model, including components for steering, obstacle avoidance, matching the speed and heading of neighbors, and braking, expressed as dynamical systems. We test whether the model can generate characteristic patterns of crowd behavior using multi-agent simulations. Here we aim to quantitatively evaluate these simulations against human crowd data. Locally, we compare individual human and model trajectories, which faces an n-body problem (e.g. classical mechanics). Globally, we compare distributions of trajectories (e.g. statistical mechanics). Method. We simulated naturalistic data collected from groups of 20 participants walking in a 12x20m arena (Warren, et al., VSS 2013). Head positions were tracked using a 16-camera motion capture system (60 Hz). In the "Grand Central" scenario, participants criss-crossed the arena, while avoiding 10 obstacles and each other. In the "swarm" scenario, participants veered left and right while staying together as a group. Each trial was simulated by initializing agents with each participant's starting position, heading, and speed, and assigning their final position as the goal; different combinations of model components were tested. Results. A local "divergence" measure computed mean agent-participant distance (error) at each time step as a function of elapsed time. Surprisingly, the mean error over all agents is only 30 cm, with a maximum of 1 m, for the best combination of model components. Measures of global traffic patterns, including occupancy heat maps and route histograms, are also compared. The results suggest that the collective behavior of human crowds can be accounted for by an empirical model of pedestrian behavior and emerges from local interactions.

Acknowledgement: This research is funded by NIH 5R01 EY010923

21.15, *9:15 am* **Modeling uncertainty and intrinsic reward in a virtual walking task** Matthew H. Tong[1](mhtong@utexas.edu), Mary M. Hayhoe[1]; [1]Center for Perceptual Systems, University of Texas Austin

When acting in the natural world, humans must balance the demands of a variety of goals, such as controlling direction and avoiding obstacles, each of which may require information from different parts of the scene.

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One theory of how these competing demands are managed, based on reinforcement learning, has been proposed by Sprague et al (ACM Transactions on Applied Perception, 2007), and postulates that gaze targets are chosen depending on the intrinsic reward of the current behavioral goals and the uncertainty about relevant environmental state. Actions, in turn, are chosen to maximize expected reward, which reflects the intrinsic importance of different behavioral goals for the subject. Despite the importance of the concept of reward in control of both gaze and actions, there is limited evidence on how such intrinsic rewards control actions and contribute to momentary sensory-motor decisions. We have measured both gaze and walking behavior in a virtual environment where subjects walk along a winding path, avoiding obstacles and collecting targets. Instructions varied on different trials concerning whether or not the obstacles and targets were relevant. We developed an avatar model, based on Sprague et al's algorithm, which performs the same task in the same conditions as humans. The model can produce paths comparable to those taken by the humans through the environment. The avatar's path varies with task instructions much as humans' do. This model allows us to estimate the intrinsic reward value of different goals by applying Inverse Reinforcement Learning techniques to the routes that subjects take through the targets and obstacles (Rothkopf and Ballard, Biological Cybernetics, 2013). These intrinsic rewards reflect the variation in path as a consequence of different task instructions and may capture path variations between subjects.

Acknowledgement: NIH grant EY05729

21.16, *9:30 am* **Fast mirroring of an opponent's action in a competitive game** Ken Nakayama[1](ken@wjh.harvard.edu), Sarah Cormiea[1], Maryam Vaziri Pashkam[1]; [1]Vision Sciences Laboratory, Department of Psychology, Harvard University

David Marr wrote that Vision is determining "what is where by looking". This privileges the role of objects, their identity and their location. Vision, however, is much more, supporting continuous action, not only with respect to objects but also to other agents. With respect to human beings, this is ubiquitous and infinitely varied. As a possible opportunity for research, consider issues prompted by contact sports. Fencing requires that one block an opponent's sabre. Boxing requires that one block an opponent's punch. In a two-person game, we describe how a blocker counters the pointing actions of an opponent. Contestants face each other, separated by a transparent window. The attacker's job is to hit one of two side-by-side targets on the window as quickly as possible. The blocker's goal is to hit this same target within a short time lag. In our first experiment, reaction times of the blocker were short (measured by the initiation of the attacker's hand movements), approximately, 100-150 milliseconds. This is much shorter than previously reported choice reaction times and suggests that the blocker is sensing some other preparatory action of the attacker. To explore the possible locus of such actions, we replicated our first experiment and added two conditions, allowing the blocker to only see the head and eyes of the attacker or allowing the blocker to only see the torso containing the arms and hand. We find that information is potentially available in each case to support the rapid action, that some subjects use just one of these potential routes whereas others can use both. In either case, the accuracy of these fast blocker responses indicates widespread information about an attacker's intentions, well before hand movements start.

Acknowledgement: NSF CCF-1231216

Attention: Control

Saturday, May 17, 8:15 - 9:45 am
Talk Session, Talk Room 2
Moderator: Hans Super

21.21, *8:15 am* **Location specific and non-specific effects of suppressed feature singletons on visual processing.** Joo Huang Tan[1](jootan@nus.edu.sg), Po-Jang Hsieh[1]; [1]Neuroscience and Behavioral Disorders Program, Duke-NUS Graduate Medical School

It is postulated that in the early stages of visual processing, lower-level features of a scene are extracted automatically to form a topological saliency map for attentional selection. Although several studies have shown that high saliency speeds up attentional selection, whether a salient target (i.e. a feature singleton) can help its region of the visual field reach conscious awareness faster and/or more often remains as yet unknown. Here, we employed a variant of the continuous flash suppression paradigm to suppress a pop-out display (a feature singleton among homogenous distractors) and tested (1) if the subliminal pop-out display reaches awareness faster than a subliminal non-pop-out display, (2) if a feature singleton can enable its region of the visual field reach awareness ahead of other regions, and (3) if the suppressed feature singleton can elicit a location non-specific effect by enabling a region of the visual field where the feature singleton does not exist to reach awareness ahead of other regions. We demonstrate that presence of a salient feature singleton enables a display to reach awareness faster. Additionally, a location's probability of gaining awareness first does indeed increase significantly when it contains a feature singleton. Interestingly, in some instances, an area of the visual field can still reach awareness faster even when the suppressed feature singleton is located in another location of the visual field. Our findings reveal that salient features facilitate conscious perception in the early stages of attentive processing in both a location specific and non-specific manner.

21.22, *8:30 am* **Two stages of attentional filtering during sequential evidence integration in human perceptual decision-making** Valentin Wyart[1,2](valentin.wyart@gmail.com), Nicholas Myers[1,3], Christopher Summerfield[1]; [1]Department of Experimental Psychology, University of Oxford, UK, [2]Laboratoire de Neurosciences Cognitives, Inserm U960, Ecole Normale Superieure, Paris, France, [3]Oxford Centre for Human Brain Activity, Department of Psychiatry, University of Oxford, UK

Categorical decisions based on noisy sensory information can be optimized by sequential sampling and integration. Cognitive psychologists have shown that human decision performance is limited not just by noise but by capacity, a constraint that emerges when competing sources of information are presented simultaneously. However, it remains unclear whether selective attention filters information at an early stage (during the processing of relevant sensory features) or at a late stage (during the integration of decision evidence). Here we recorded human EEG signals from 17 healthy subjects whilst they monitored two streams of Gabor patterns presented synchronously at 3 Hz to the left and right of fixation. At stimulation offset, subjects were probed to make a categorization judgment on one of the two streams. In the 'focused attention' condition, subjects were cued before stimulation onset as to which stream would be probed. In the 'divided attention' condition, which stream would be probed was only revealed after stimulation offset. We regressed human EEG signals against model-based variables representing the perceptual, decision and action-based information provided by each sample, and studied the stage(s) at which attention filtered information in the two conditions. Our results revealed two distinct stages at which attentional filtering occurs during sequential evidence integration. Diverting attention away from one stream by cueing it as irrelevant had a modest impact on the neural encoding of perceptual information, but precluded its conversion into decision information. By contrast, under divided attention, decision information from both streams was filtered only prior to integration, leading to a 'leaky' process that manifests itself as a bias to base decisions on the most recent evidence. The existence of distinct early and late filtering stages reconciles accounts of attentional selection that emphasize biased competition vs. a central bottleneck, and places important constraints on decision-theoretic models of perceptual categorization.

21.23, *8:45 am* **Role of vergence during eye fixation in orienting visual attention** Hans Supèr[1,2,4](hans.super@icrea.cat), Josep Marco[1,2], Laura Perez Zapata[1], Jose Cañete Crespillo [3], Maria Solé Puig[1,2]; [1]Dept Basic Psychology, Faculty of Psychology (UB), [2]Institute for Brain, Cognition and Behavior (IR3C), [3]Mental Health Dept, Consorci Sanitari del Maresme, [4]Catalan Institution for Research and Advanced Studies (ICREA)

Neural mechanisms of attention allow selective sensory information processing. Top-down deployment of visual-spatial attention involves extensive cortical feedback connections from frontal cortical regions to lower sensory areas. Here we provide evidence for a novel circuit in guiding top-down attention. In a series of standard attention paradigms (Solé et al., 2013), subjects fixated on a central spot and were required to indicate the change in orientation of one of eight peripheral bars by pressing a button. In trials where the spatial location of the peripheral target was cued, we found strong eye vergence (convergence) while in non-cued trials vergence was weak. Similarly, for high-salient targets, vergence was strong compared to that recorded after presenting low-salient stimuli. Thus when orienting visual attention, the eyes briefly converge. Correspondingly, we recorded visual evoked responses (vERPs). The results show that vERPs reflecting attention deployment (N2pc) were a function of the eye vergence. Moreover, we provide evidence that vergence correlates with the perception of the target. Eyes briefly converge after a perceived target but not after an unnoticed one. Furthermore, we measured vergence in children diagnosed with Attention Deficit Hyperactivity Disorder (ADHD) while performing a cue/no-cue task and compared the results to age-matched controls. A strong vergence was detected in the control group but not in the ADHD group. The near-triad or accommodation reflex does not appear to be an explanatory factor for the observed vergence. We propose that our findings show a novel role for vergence in visual-spatial attention and provide evidence for a feed-forward, oculomotor circuit in top-down visual attention. Solé Puig M, Pérez Zapata L, Aznar-Casanova JA, Supèr H (2013) A Role of Eye Vergence in Covert Attention. PLoS ONE 8(1): e52955. doi:10.1371/journal.pone.0052955

21.24, *9:00 am* **The timecourse of the attentional bias to regularities** Jiaying Zhao[1,2](jiayingz@psych.ubc.ca), Nicholas B. Turk-Browne[3]; [1]Department of Psychology, University of British Columbia, [2]Institute for Resources, Environment and Sustainability, University of British Columbia, [3]Department of Psychology, Princeton University

Knowledge about the structure of an environment can help us perceive and act more efficiently. But how do we find such regularities in the first place when they are embedded in noisy and complex visual input? We recently showed that attention is naturally biased to regularities, prioritizing locations and features where they can be found (Zhao, Al-Aidroos, & Turk-Browne, 2013). A normative explanation of this effect is that it speeds the extraction of these regularities, such that attention can be released to support processing of information about which we have greater uncertainty. Accordingly, we hypothesized that the bias for regularities should dissipate over time. Experiment 1 examined the timecourse of spatial attention to regularities. Observers were presented with multiple streams of shapes that were interrupted occasionally by visual search arrays. One of the streams was generated from shape triplet regularities. During the first of three epochs of exposure, we found as before that attention prioritized the structured location, as indexed by facilitated search performance at that location. However, by the final epoch of exposure, this benefit had disappeared. Experiment 2 generalized this effect to feature-based attention. Observers were now presented with a single stream of shapes of different colors that was interrupted by visual search arrays with a color singleton. The shapes in one color again appeared in triplet regularities. We found as before that attention prioritized the structured color, as measured by attentional capture for singletons of that color. This time, the bias was most evident in the second of three epochs, but critically, this benefit also disappeared by the final epoch. In sum, the attentional bias for regularities is transient, but of sufficient duration to allow for rapid statistical learning. Such attentional disengagement may allow for the exploration and acquisition of more complex or new forms of structure.

Acknowledgement: NIH R01 EY021755

21.25, *9:15 am* **Statistical regularities alter the spatial scale of attention** Yu Luo[1](yuluo2008@hotmail.com), Jiaying Zhao[1,2]; [1]Department of Psychology, University of British Columbia, [2]Institute for Resources, Environment and Sustainability, University of British Columbia

When looking out at a scene, we can flexibly direct our attention to individual objects (e.g., a specific tree), or to the whole scene (e.g., a forest). Here we examine how the learning of statistical regularities prioritizes individual objects in the array (local attention) or the entire array (global attention). In Experiment 1, we examined whether local regularities draw attention to a local scale. Observers viewed arrays of nine colored objects arranged in a 3x3 matrix. Each matrix was either in the shape of a square or a diamond. Each individual object was either a square or a diamond. Unbeknownst to the observers, the matrix either contained three triplets of colored objects (i.e., local regularities) in the structured condition, or contained colored objects in a random arrangement in the random condition. The task was to indicate, as fast as possible, either the shape of the individual object, or the global shape. We found that observers were reliably faster at identifying individual objects but slower in identifying the global shape, when the array was structured vs. random. This suggests that local regularities facilitate local attention and impede global processing. In Experiment 2, we examined whether global regularities cue global attention. Everything was the same as in Expt1 except that there were no triplets. Instead, the four corners of the matrix contained a color quadruple (i.e., global regularities) in the structured condition. We found that observers were reliably faster at identifying the global shape but slower in identifying individual objects, in the structured vs. random condition. This suggests that global regularities facilitate global attention and impede local processing. These findings demonstrate that spatial regularities can determine whether attention is directed to individual elements or to the entire scene, providing evidence for the influence of statistical learning on the spatial scale of attention.

21.26, *9:30 am* **Global/local object structure affects memory-driven capture of attention** Markus Conci[1](conci@psy.lmu.de), Hermann J. Müller[1]; [1]Department of Psychology, Ludwig-Maximilians-University, Munich, Germany

Visual working memory and selective attention have shown to reveal close relationships, as contents in memory can determine where attention is deployed. For instance, visual search for a target object is typically slowed when a concurrent distractor matches with what is currently held in working memory (Soto et al., 2005; Olivers et al., 2006). Here, we investigated whether the structure of an object in memory affects the degree to which it reveals attentional capture. For instance, objects can be represented at multiple hierarchical levels, but in general, global object levels are prioritized over more local levels (e.g. Conci et al., 2011). In our study, we investigated the influence of such hierarchical structure by asking participants to memorize an object that comprises both global and local levels of representation. Performance in a subsequent search task revealed a graded influence showing a pattern of memory-driven capture: Search was slowed when a distractor matched with current memory contents, relative to an unrelated baseline distractor. Moreover, the capture effect was more pronounced when the distractor matched with the global object representation as compared to the local object level. Subsequent analyses indicated that not only attentional capture reflected the inherent object structure, but the memory representation itself was graded. In sum, these results show a global bias of objects represented in working memory, affecting how attention is deployed. This suggests that the perceptual structure of an object directly determines the fidelity with which that object is hierarchically represented in working memory.

Acknowledgement: German Research Foundation (DFG, grant: CO 1002/1-1) LMUexcellent 'Junior Researcher Fund'

Motion Perception: Neural mechanisms and modeling

Saturday, May 17, 10:45 am - 12:30 pm
Talk Session, Talk Room 1
Moderator: Concetta Morrone

22.11, *10:45 am* **Bidirectional manipulation of GABAergic inhibition in MT: A comparison of neuronal and psychophysical performance** Liu Liu[1,2](liu.liu2@mail.mcgill.ca), Christopher Pack[1,2]; [1]McGill University, [2]Montreal Neurological Institute

Based on their responses to small and large stimuli, MT neurons can be classified as surround-suppressed (SS) or non-surround suppressed (NS). Surround suppression in MT has often been associated with a loss of perceptual sensitivity for large, moving stimuli (Tadin et al. 03). Weakened spatial suppression in certain cohort of subjects is therefore thought to be due to reduced efficacy of GABAergic inhibition, but these links have not been probed experimentally. Here we examined the causal role of GABAergic inhibition in MT responses. Monkeys performed a 2AFC motion direction discrimination task with Gabor patches of various sizes at a fixed duration (typically 50 ms). We found that the performance of SS neurons generally correlated more strongly with perceptual reports, as monkeys found the motion direction of larger stimuli more difficult to discriminate. Surprisingly, NS neurons consistently outperformed the monkey for large stimuli, suggesting sub-optimal pooling of the neurons to perform the task. To interpret these results and establish a causal relationship, we first directly confirmed that MT neurons are causally involved in motion direction discrimination of Gabor patches by injecting muscimol to reversibly inactivate MT. We found that inactivation of MT reduces performance for Gabor and random dots stimuli to the same degree. While monitoring the neuronal response, we injected GABAergic agents to bidirectionally manipulate inhibitory efficacy. We found GABA suppresses untuned responses by increasing the spiking threshold, and that GABA antagonists have the opposite effects. This raises the possibility that the additional inhibition associated with surround suppression renders SS neurons more direction selective and thus more informative about motion direction. However, we found that local blockade of GABA receptors did not diminish surround suppression, as previously observed in V1. It thus appears that the contribution of inhibition to surround suppression is more complex and dynamic than previously thought.

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22.12, *11:00 am* Development of visual BOLD response in infants

Maria Concetta Morrone[1,2](concetta@in.cnr.it), Laura Biagi[2], Sofia Crespi[3], Michela Tosetti[2]; [1]Department of Translational Research on New Technologies in Medicine and Surgery, University of Pisa, [2]IRCCS Fondazione Stella Maris, [3]Faculty of Psychology - Università Vita-Salute San Raffaele., Milan

It is commonly assumed that early visual areas (V1-V2, and also retina and LGN) develop first, followed by higher associative cortices (V3-V6-MT). However, there have been no direct measurements of the maturation of individual cortical areas in newborns by MR imaging methods to confirm this hypothesis. In adults, motion direction selectivity is mediated by an extensive network of areas (V1, V3, V6, LO, MT, VIPS, Pre-Cuneus, PIVC). Here we use fMRI to investigate if this neural network is functional in infancy. We measure BOLD responses to flow versus random motion stimuli in 10 cooperative 7-week-old infants, and the resting state activity in 5 of those infants during sleep. The results show that at 7 weeks of age the major circuits mediating the response to flow motion were operative and adult-like, with stronger response to coherent spiral flow motion than random speed-matched motion (Morrone et al 2000, Nature Neuroscience) in parietal-occipital area (presumed MT+), pre-cuneus, posterior parietal (V6) and an area corresponding anatomical to PVIC, which in adults receives visual-vestibular input (Cardin & Smith 2010). As in adults, V1 does not respond preferentially to coherent motion. Resting-state connectivity maps indicate strongly reduced connectivity between V1 and the parietal-occipital regions selective for flow motion (putative MT+), suggesting the existence of an alternative input that bypasses V1. The results revealed an unexpected maturation of the motion analysis circuit of the associative area, probably not mediated by striate cortex, and suggest that the limiting factor in the development of motion selective cortical response are the development of the subcortical input and of the cortical-cortical connections.

Acknowledgement: ESCLAIN- ERC ADV GRANT

22.13, *11:15 am* Neural dynamics of fine direction-of-motion discrimination

Jacek Dmochowski[1](jdmochow@stanford.edu), Anthony Norcia[1]; [1]Stanford University, Department of Psychology

The visual system can discriminate small differences in direction of motion despite the relatively broad direction-tuning of motion selective cells in visual cortex. Here we used high-density EEG to probe the neural basis of fine direction discrimination. Fifteen neurotypical adults performed 210-280 trials of a choice reaction time task. The random dot stimulus consisted of 1 second of random motion followed by 1 second of coherent motion. The mean direction of coherent motion was selected from one of seven directions centered on vertical (90deg) ranging from 80 to 100 degrees in increments of 3.4 degrees. Subjects indicated the perceived direction of motion (left or right of vertical) with a button press. We employed a novel technique, "Reliable Components Analysis" (Dmochowski et al., 2012) which computes projections of the EEG that maximize the trial-to-trial reliability/consistency. The first reliable component locked to stimulus onset had a midline-symmetric topography with a maximum over the parietal lobe. The time course of this component exhibited a "ramping" trajectory whose level and slope discriminated between the angular deviations from vertical, but not the absolute directions-of-motion. The second and third reliable components did not depend on offset size and may reflect pre-categorical coherent motion responses. Activity time-locked to the button press exhibited a peak at the time of behavioral response, with a steeper gradient of response leading to the peak for larger offsets for the first component. The second component did not depend on offset and was sharply peaked at response time, suggesting a motor origin. Discrimination of near-threshold-level changes in direction-of-motion can be decoded from electric potentials above parietal cortex. These potentials appear to be the output of a categorization process for direction. The time-course of the differential response is consistent with an integration process that is longer for more difficult discriminations.

22.14, *11:30 am* Forward displacement of expanding and contracting lines beyond their point of disappearance

Robert Tilford[1](r.tilford@sussex.ac.uk), Romi Nijhawan[1]; [1]School of Psychology, University of Sussex

It is known that a moving object that vanishes is not perceived to overshoot its endpoint. For instance, the flash-lag effect (FLE) - where a moving object appears ahead of a collocated flash - is abolished when the moving stimulus disappears with the flash. Here we show that the disappearing length of an expanding (contracting) line is perceived to be larger (smaller) than an identical flashed or continuous comparison line. In three experiments (2AFC method), dynamic vertical lines expanded or contracted to the left (right) of fixation before disappearing. On the right (left) of fixation one of the following types of static comparison line was presented: 1) flashed at termination of dynamic line, 2) continuous, offset synchronous with dynamic line, or 3) continuous, no offset. In all experiments, the size of the comparison line appeared to substantially lag the size of the dynamic line. In addition, these lags tended to be greater for contracting than for expanding lines. Results for comparison lines described in 1-3 above: 1) 91ms Expanding, 177ms Contracting; 2) 143ms Expanding, 207ms Contracting; 3) 97ms Expanding, 256ms Contracting. This is the first demonstration of dynamic stimuli with abrupt offset overshooting their endpoints, and exhibiting an effect at flash-termination. Several flash-lag accounts are grounded on the absence of an effect when both stimuli vanish together. Our results show that: a) a future trajectory is not necessary for the lag effect, and b) a flash is not necessary for forward displacement. We suggest that in nature it is inferred that disappearing objects have rapidly receded, and so their final positions are extrapolated towards an implicit vanishing point. This is supported by a larger effect in contracting motion. Expanding motion is inconsistent with disappearance and so the overshoot effect is diminished.

Acknowledgement: BBSRC

22.15, *11:45 am* Rethinking the aperture problem: a story of competing priors

Edgar Walker[1](eywalker@bcm.edu), Wei Ji Ma[2]; [1]Department of Neuroscience, Baylor College of Medicine, [2]Center for Neural Science, New York University

How the visual system resolves ambiguity is a fundamental problem in vision science. A classic example is the aperture problem, in which a moving grating is viewed through an aperture. Although the stimulus is consistent with many motion directions, it typically produces a reliable motion direction percept. However, since very few studies have explored the effect of the shape of the aperture and of its orientation relative to the grating on perceived motion direction, the brain's strategy for resolving ambiguity in this problem is not fully understood. We conducted an experiment in which subjects reported the perceived motion direction of a grating moving behind an elliptical or rectangular aperture with a variable aspect ratio and variable relative orientation. We found strong effects of relative orientation, aspect ratio, and shape on the perceived motion direction. These effects could not be captured by previous models – one based on a prior favoring low speeds, and one based on line terminators. Instead, we reframed the observer's decision process as Bayesian inference on the motion direction of an infinitely long patterned strip with fixed but unknown width viewed through the aperture. In the model, the observer a) computes for each candidate motion direction the speed and minimum strip width consistent with the scene, b) assigns posterior probability using both the low-speed prior and a prior we propose here, which favors narrower strips, and c) reports the posterior mean. The resulting model not only outperformed the other two models, but also captured the observed dependencies with high accuracy. One potential interpretation of the narrow-strip prior is as a "little-unseen stuff" prior, favoring scenes that require the fewest assumptions about unobserved regions of the scene. Perhaps our brain resolves ambiguity by performing a process analogous to model selection, where simpler models are favored over complex ones.

22.16, *12:00 pm* Unified representation of motion and motion streak patterns in a model of cortical form-motion interaction

Stephan Tschechne[1](stephan.tschechne@uni-ulm.de), Heiko Neumann[1]; [1]Ulm University Inst. f. Neural Information Processing

Problem. Direction selective neurons in visual cortex (V1) encode spatio-temporal movements of visual patterns. It has been suggested that motion directions are also spatially encoded in the form channel as oriented motion streaks (Burr, Curr. Biol., 2000), while only fast motions lead to motion streak patterns (Apthorp et al., Proc. Roy. Soc. London B, 2013). Geisler (Nature, 1999) proposed that motion streaks aid determining visual motion direction estimation while their awareness is suppressed in normal vision conditions (Wallis & Arnold, Curr. Biol., 2009). The underlying neural mechanisms of such form-motion interaction are, however, still unknown. Method. We propose a neural model that acquires data from an event-based vision sensor that responds to temporal changes in the input intensity. Model area V1 uses spatio-temporal filters to detect visual motion and forwards activations to be integrated in model area MT. Orientation-selective contrast cells in model areas V1 and V2 spatially integrate recent visual events and respond to oriented structures parallel to movement direction when sufficiently fast motion is presented. Form cells' responses temporally cease already for slow motions. Results and Conclusion. We probed the model with dark/light random dot patterns moving at different directions and speeds, replicating experimental settings. For higher speeds oriented contrast-sensitive cells are co-activated along an orientation parallel to the motion direction, viz., signaling motion streaks or speedlines. For slow motions no such responses occur.

 See page 3 for Abstract Numbering System

Adaptation effects confirm experimental findings from psychophysics. The model suggests that motion streaks occur in the form channel as a direct consequence of fast coherent motions along single directions without the need to assume separate motion channel representations. The model makes predictions concerning the strength of the streak patterns and sheds new light upon mechanisms of computing motion from form.

Acknowledgement: DFG SFB/TR 62

22.17, *12:15 pm* **No dedicated color motion system** Remy Allard[1](remy.allard@umontreal.ca), Jocelyn Faubert[1]; [1]Visual Psychophysics and Perception Laboratory, Universite de Montreal

The existence of a color motion system distinct from both the luminance and feature tracking motion systems remains controversial. In the current study, we used a mask known to affect luminance-defined motion processing but which should not affect distinct color-defined motion processing: a static, luminance-defined pedestal at high contrast. To neutralize feature tracking, the motion (3.75 Hz) was presented in the near periphery (2 to 3 degrees of eccentricity) at a spatial frequency (~1 cpd) beyond the attentional resolution acuity. The results showed that, in a direction discrimination task, the luminance-defined pedestal affected luminance- and color-defined contrast thresholds by similar proportions (~10x at the highest pedestal contrast) and that this masking was orientation specific as a similar mask orthogonal to the signal modulation had little impact on luminance- and color-defined contrast thresholds. Given that L- and M-cone pathways merge at a processing level that is not orientation specific (i.e., ganglion cells, which have center-surround receptive fields), the masking of a luminance pedestal must interfere with higher processing stages within the luminance pathway where cells are orientation selective (e.g., simple cells). Furthermore, a static luminance-defined mask should not generate any substantial response from cells sensitive to luminance-defined motion (e.g., complex cells), so even if distinct luminance and color motion pathways merged after independent motion extractions, a static, luminance-defined mask should not impair color-defined motion processing. The similar vulnerabilities of luminance- and color-defined motion processing to a static, luminance-defined mask suggest that, when the feature tracking is neutralized, luminance- and color-defined motions are processed by the same motion system. We conclude that there is no dedicated color motion system.

Acknowledgement: This research was supported by NSERC discovery fund awarded to Jocelyn Faubert

Attention: Features and objects

Saturday, May 17, 10:45 am - 12:30 pm
Talk Session, Talk Room 2
Moderator: Emily Ward

22.21, *10:45 am* **Stimulus competition modulates the joint effects of spatial and feature-based attention on visual sensitivity** Alex White[1,2](alex.white@nyu.edu), Martin Rolfs[2,3], Marisa Carrasco[1,4]; [1]Department of Psychology, New York University, [2]Humboldt University Berlin, [3]Bernstein Center for Computational Neuroscience, [4]Center for Neural Science, New York University

Goal: Selectively monitoring a location in the peripheral visual field improves perceptual judgements and enhances neural responses to stimuli at that location. In addition, attending to a particular feature value, such as a specific color, improves processing of items with that feature across the visual field. We investigated whether and how spatial and feature-based attention interact to modulate visual sensitivity in a discrimination task. Methods: Observers monitored overlapping groups of dots for a subtle change in color saturation, which they had to localize as being in the upper or lower hemifield. At the start of each trial, a pre-cue indicated the most likely side (left or right), color (red or green), or both side and color of the target saturation change. The location cue and the color cue could each be valid, neutral, or invalid, and we measured sensitivity (d') for every combination. In Experiment 1, only one patch of dots changed in saturation. In Experiment 2, there were three other saturation changes (distractors) simultaneous with the target change. A post-cue indicated which dots to judge. Results: For both cue types, d' was higher in valid than invalid trials. When only a single saturation change occurred, the location and color cueing effects were statistically independent and approximately additive. However, when competing saturation changes occurred simultaneously with the target saturation change, the location and color cueing effects interacted. The effect (i.e. valid d' – invalid d') of each type of cue was strongest when the other type of cue was valid. Moreover, spatial attention was only effective in modulating sensitivity for attended colors. Conclusion: In light of these findings and previous physiological studies, we conclude that spatial and feature-based attention can operate independently. However, their joint consequences for perception depend on the presence of competing visual information.

Acknowledgement: Supported by NIH R01 EY016200 to MC and by a DFG Emmy Noether grant (RO 3579/2–1) to MR

22.22, *11:00 am* **Feature-based attention elicits surround-suppression in color space** Viola S. Störmer[1](vstormer@fas.harvard.edu), George A. Alvarez[1]; [1]Department of Psychology, Harvard University

When focusing on a particular spatial location, input at the attended location is enhanced, and information at nearby locations is suppressed. While this surround suppression is well documented for spatial attention (e.g., Hopf et al., 2006), it is less clear whether similar mechanisms operate in feature-based attention. We investigated whether surround suppression exists in color space when attending to particular colors. Observers viewed overlapping sets of colorful moving dots in the left visual field (e.g., yellow among blue dots), and separate overlapping sets of dots in the right visual field (e.g., orange among blue dots). The task was to attend to two colors (e.g., yellow and orange) and to detect brief intervals of coherent motion. The colors were randomly chosen from the CIElab color space on each trial, such that target and distractor colors were on opposite sides of the color wheel. The two target colors were either the same color, or differed from each other in steps of 10° on the color wheel, up to 60° apart. We found that accuracy was highest when the target colors were identical, and decreased as the difference in color increased, reaching a minimum at 30° (identical vs. 30°, $t(19)=2.4$; $p=0.03$). Interestingly, performance gradually increased when the target colors became more distinct from each other (i.e., 30° vs. 60°; $p=0.03$), with performance at 60° no worse than when attending to a single color ($p=.68$). Thus, selecting two perceptually similar (but subtly different) colors is more difficult than selecting two perceptually distinct colors. Similar results were obtained using a visual search task. These results suggest that feature-based attention contains a narrow inhibitory surround in color space that operates across the entire visual field, supporting models of attention in which local inhibition in feature space enhances top-down selection of task-relevant objects.

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22.23, *11:15 am* **Neural coding of perceptual features is enhanced when they are task relevant** Emily Ward[1](emily.ward@yale.edu), Marvin Chun[1]; [1]Department of Psychology, Yale University

Multi-voxel pattern analysis has allowed us to investigate neural coding of stimulus-specific visual information by constructing high-dimensional representational spaces. Despite their utility for exploring visual representation, the extent to which multi-voxel relationships change as a function of task or attentional demands has not been widely explored. We scanned 10 participants while they viewed items that varied along three feature dimensions: shape, color, and texture. Participants either viewed the items passively, or were instructed to attend to one of the dimensions (e.g. "shape") and indicate the feature value for each item (e.g. "circle", "triangle", or "square"). This allowed us to examine neural discriminability among feature values with and without an explicit task, and more importantly, when a particular dimension was task relevant or not. In the lateral occipital cortex, feature values could not be classified during passive viewing, but could be classified when participants performed the feature-relevant task. Critically, across all tasks, task-relevant features (e.g. "circle" when attending to shape) could be classified, but task-irrelevant features (e.g. "red" when attention to shape) could not. These results are consistent with previous studies that show category learning can fine tune neural representations (Folstein et al., 2012), and widespread cortical tuning towards the task-relevant objects and away from task-irrelevant objects (Cukur et al., 2013). Our results show that task relevance impacts the representation of even simple object features. This suggests that representation in high-level visual areas may dynamically shift to facilitate behavior.

22.24, *11:30 am* **The time-course of feature-selective attention inside and outside the focus of spatial attention** Søren K. Andersen[1,2](skandersen@abdn.ac.uk), Steven A. Hillyard[2]; [1]School of Psychology, University of Aberdeen, Aberdeen, UK, [2]Department of Neurosciences, University of California at San Diego, La Jolla, USA

Previous research on attentional selection of features has yielded seemingly contradictory results: many experiments have found a 'global' facilitation of attended features across the entire visual field, whereas classic event related potential (ERP) studies reported an enhancement of attended features at the attended location only. To test the hypothesis that these conflicting results

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can be explained by temporal stimulus differences, we compared the time-course of feature-selective attention inside and outside the spatial focus of attention. We presented fields of randomly moving purple dots on either side of fixation. Participants were audio-visually cued to attend to either red or blue dots on either the left or right side in order to detect brief coherent motion targets. After a delay, which allowed participants sufficient time to shift attention to the cued location, the purple dots on both sides changed color simultaneously so that half of them became blue and the other half red. Each of these four dot populations flickered at a different frequency, thereby eliciting distinguishable steady-state visual evoked potentials (SSVEPs). This allowed us to concurrently measure the time-course of feature-selective attentional enhancement of stimulus processing in visual cortex after onset of the attended feature on both the attended and the unattended side. The onset of feature-selective attention on the attended side occurred over 100 ms earlier than on the unattended side. The finding that feature-selective attention is not spatially global from the outset, but that its effect spreads to unattended locations with a temporal delay resolves previous contradictions between studies that found global selection of features and studies that failed to find such global selection because they used briefly flashed stimuli. We speculate that the observed delay might be caused by the time needed to coordinate attentional control signals between hemispheres, although the exact mechanisms are still unknown.

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22.25, *11:45 am* Measuring the salience of an object in a scene

Alasdair Clarke[1](a.clarke@ed.ac.uk), Michal Dziemianko[1], Frank Keller[1]; [1]Institute for Language, Cognition and Computation, School of Informatics, University of Edinburgh

Over the past 15 years work on visual salience has been restricted to models of low-level, bottom-up salience that give an estimate of the salience for every pixel in an image. This study concerns the question of how to measure the salience of objects. More precisely, given an image and a list of areas of interest (AOIs), can we assign salience scores to the AOIs that reflect their visual prominence? Treating salience as a per-object feature allows us to incorporate a notion of salience into higher-level, cognitive models. There is increasing evidence that fixations locations are best explained at an object level [Einhauser et al 2008, JoV; Nuthmann & Henderson 2010, JoV] and an object-level notion of visual salience can be easily incorporated with other object features representing semantics [Hwang et al 2011, VisRes; Greene 2013, FrontiersPsych] and task relevance]. Extracting scores for AOIs from the saliency maps that are output by existing models is a non-trivial task. Using simple psychophysical (1/f-noise) stimuli, we demonstrate that simple methods for assigning salience score to AOIs (such as taking the maxima, mean, or sum of the relevant pixels in the salience map) produce unintuitive results, such as predicting that larger objects are less salient. We also evaluate object salience models over a range of tasks and compare to empirical data. Beyond predicting the number of fixations to different objects in a scene, we also estimate the difficulty of visual search trials; and incorporate visual salience into language production tasks. We present a simple object-based salience model (based on comparing the likelihood of an AOI given the rest of the image to the likelihood of a typical patch of the same area) that gives intuitive results for the 1/f-noise stimuli and performs as well as existing methods on empirical datasets.

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22.26, *12:00 pm* Attentional constraints on human foraging

Arni Kristjansson[1](ak@hi.is), Omar Johannesson[1], Ian M. Thornton[2]; [1]Department of Psychology, University of Iceland, [2]Department of Cognitive Science, University of Malta

How do humans search for multiple targets from more than one category? In contrast to animal research, such foraging has been largely neglected in human visual search, typically involving single-category, single-target trials that terminate with the first response. Here, we introduce a new iPad foraging task where observers cancel a series of targets among distractors by tapping them until all are gone. The number of possible target types and distractor types can vary independently. We asked how foraging changed as a function of target complexity. During feature-based foraging 16 naïve observers cancelled 40 green and red disks among yellow and blue distractors (or vice versa). During conjunction-foraging they cancelled red disks and green squares among green disks and red squares (or vice versa). Our main dependent variable was the number of "runs" per trial, which could vary between 40, if a target switch occurred after each response, and 2, if sequential subset searches were carried out. Random switching would result in mean run length of 20. For feature-based foraging, behavior was characterized by many short runs (M = 14), suggesting that observers could simultaneously maintain two or more color templates in mind and were happy to switch between them. For conjunction-based foraging, the pattern was dramatically different: observers focused on one target-type, finishing most or all of those before switching to the other target type (M = 5). In both conditions, more runs resulted in less overall movement, suggesting that switching might be the more "optimal" strategy. For conjunction foraging, this was mostly driven by 4 observers who were able to switch frequently despite the increase in target complexity. Our main, novel finding -- the striking difference between conjunction and feature-based behavior -- suggests that attention imposes a very sharp constraint on human foraging.

Acknowledgement: Icelandic Research Fund, Research fund of the University of Iceland

22.27, *12:15 pm* The Effect of Semantic and Syntactic Object Properties on Attentional Allocation in Naturalistic Scenes

George Malcolm[1](glmalcolm@gwu.edu), Sarah Shomstein[1]; [1]Department of Psychology, The George Washington Unviersity

Humans preferentially attend to objects over backgrounds when viewing scenes (e.g., Henderson, 2003), making object properties an integral component to understanding attentional orienting. Previous research investigating object properties' effect on attention has generally focused on low-level features (e.g., color; Wolfe, 1994) or boundaries (e.g., Egly et al., 1994). However, real-world environments are cluttered with different objects that are rich with semantic properties. Here we investigated how semantic and syntactic relationships between objects affect attentional allocation. In an initial series of experiments designed to test semantic biasing of attention, we presented participants with an object at fixation and two more in the periphery that varied in semantic relation to the fixated object (e.g., a mailbox at fixation and an envelope and light bulb in the periphery). Objects appeared for a duration ranging from 250-2000ms prior to target/distractors onsetting on the objects. The semantic relationship between objects was found to facilitate responses to targets on semantically related objects at earlier durations (750ms), while at longer durations (>1250ms) inhibition-of-return biased attention to targets on non-related objects. The results thus demonstrate that semantic information affects attentional allocation early and, in particular, biases in favor of semantically-related objects. A series of eye-tracking experiments were then conducted in order to examine syntactic as well as semantic relations of supporting surfaces on attentional allocation. It was observed that participants initiated saccades faster to objects on the same surface as well as to semantically related surfaces. Taken together, these results suggest that, despite semantic and syntactic information not predicting target location, the visual system continually utilizes this information to bias attentional allocation when viewing naturalistic displays.

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Saturday Morning Posters

Visual memory: Objects, features and individual differences

Saturday, May 17, 8:30 am - 12:30 pm
Poster Session, Jacaranda Hall

23.301 **Ponzo inducers in the working memory produce Illusory line length perception** Feitong Yang[1](ft.yang@jhu.edu), Jonathan Flombaum[1]; [1]Department of Psychological and Brain Sciences, Johns Hopkins University

Visual information was traditionally thought to flow from the perception to the memory. Over time, however, it has become clear that memory of various forms plays a role in perception. Priors influence best inferences and context can facilitate recognition. But the role of memory is typically thought of in terms of long-term memory. We sought to investigate the possibility that the contents of visual working memory influence online perception. In each trial of our experiment one of three Ponzo railway figures was presented, and participants were instructed to remember the figures, about which they were also probed in a subsequent change detection paradigm. Critically, during the delay period of the change detection task, two horizontal lines appeared for 100 ms, and participants made an online judgment identifying the longer of the two lines. In 50% of trials the two lines were actually equal in length. But results showed that the line near the narrow end of the memorized Ponzo figure was typically perceived to be longer. (An effect in the same direction was obtained in the trials with lines that differed in length.) We ruled out the possibility that the effect was caused by an afterimage in three more experiments: a) increasing the delay time from the Ponzo figure to the two lines, b) adding a white noise mask after the Ponzo figure, and c) adding a random line mask after the Ponzo figure. These experiments replicated the effect —the figure in memory influenced the perception of line length from trial to trial. These results are consistent with recent work demonstrating that visual working memory activates early visual cortex in content specific ways. And more broadly, they suggest that the current contents of visual working memory support online perception.

23.302 **Visual search for digits is faster when numerical and physical size are congruent** Kenith Sobel[1](k.sobel@mac.com), Amrita Puri[1]; [1]Department of Psychology and Counseling, University of Central Arkansas

Do the semantic associations of alphanumeric characters influence the efficiency of visual search? Attempts to answer this question have typically suffered from a confound between conceptual and perceptual features because manipulating the meaning of an alphanumeric character entails manipulating its shape as well. By carefully controlling shape features, Lupyan (2008) found an influence of letter category on visual search. Here we extended these findings to visual search for digits and wondered if numerical and physical size would interact to yield faster response times when the two are congruent than when incongruent. The numbers 2, 3, 8, and 9 were used for search items in all conditions. In congruent conditions the numerically larger digits were slightly physically larger than the numerically smaller digits and vice versa for the incongruent conditions. In the larger magnitude conditions targets were numerically larger (8 and 9) among numerically smaller distractors (2 and 3) and vice versa for the smaller magnitude conditions. Eighty participants were randomly assigned to one of four conditions: larger magnitude/congruent, larger magnitude/incongruent, smaller magnitude/congruent, and smaller magnitude/incongruent. Each search array contained one of the two target digits and varying numbers (4, 6, or 8) of distractors. Participants indicated the side of the display containing the target with a keypress. Mean correct response times were submitted to ANOVA to compare differences between congruent/incongruent, numerically larger/smaller, and physically larger/smaller conditions. Only the congruent/incongruent comparison yielded significant differences. As hypothesized, visual search is faster when semantic and physical attributes are congruent than when incongruent. Perhaps the mismatch interferes with the maintenance of a complex target template. Future studies will explore this possibility by determining the effect of congruence on search for a single target.

23.303 **Aging and visual memory: Modified method of single stimuli reveals biases and imprecision** J. Farley Norman[1](farley.norman@wku.edu), Jacob Cheeseman[1], Michael Baxter[1], Kelsey Thomason[1], Olivia Adkins[1], Connor Rogers[1]; [1]Department of Psychological Sciences, Western Kentucky University

Twenty younger and older adults participated in two experiments that evaluated their ability to visually discriminate lengths. Over the past century, some investigators have required participants to judge test stimuli relative to a single implicit standard (i.e., have used the method of single stimuli). In the current experiments, we not only asked participants to compare lengths relative to a single implicit standard, but to two implicit standards simultaneously. Performance for this latter task has never previously been investigated. The primary purpose of the experiments was to determine whether human adults (of any age) can effectively learn, remember, and utilize two implicit standards within a single block of experimental trials. The results demonstrated that while human adults can accurately discriminate test lengths relative to a single implicit standard, they cannot accurately discriminate lengths relative to two implicit standards simultaneously. Under these conditions, significant and large biases emerge. In addition, the discriminations become less precise. Human adults cannot effectively learn, remember, or utilize two implicit standards simultaneously. The results of the current study document a fundamental limitation in human visual memory. We also found (unlike other visual tasks) that increases in age do not adversely affect the ability to visually discriminate lengths relative to implicit standards.

23.304 **Building tolerant long-term memories through (object) persistence** Mark W. Schurgin[1](maschurgin@jhu.edu), Zachariah M. Reagh[2], Michael A. Yassa[3], Jonathan I. Flombaum[4]; [1]Psychological and Brain Sciences, Johns Hopkins University

The phrase, "It's a bird, it's a plane, it's Superman!" epitomizes the motivation for Kahneman, Treisman & Gibbs' (1992) influential object file theory. The point: the same object can appear different to an observer over multiple encounters, requiring token representations of spatiotemporal identity—persistence—independent from surface properties. One advantage of such token representations is that they can support the construction of tolerant long-term memories, what is often identified as the central problem in object recognition. Tagging persistence independent from surface appearance can teach an observer just how different an object can look from itself. What is a Superman such that it can look like a bird and a plane? To investigate this issue, we used apparent motion to manipulate the persistence of objects encountered during the incidental encoding phase of a long-term memory experiment. In all trials participants saw a single object repeated twice, either in a spatiotemporally continuous or discontinuous path. During a surprise test, participants viewed a stream that included old objects, similar objects, and completely new objects (relative to encoding). They were instructed to identify the status of each test object. Performance was significantly better for objects observed in a continuous motion stream during encoding. In a second experiment, each encounter during encoding was embedded in independent noise. We expected that object persistence should facilitate the combination of independently noisy encounters to produce tolerant memories. Indeed, during the surprise test phase, observers were more likely to correctly classify old objects perceived continuously and were also more likely to classify their similar foils as 'old.' Several control experiments and conditions precluded simple inattention-dependent accounts of the effects. These results suggest an important role for well-characterized features of online visual cognition in the construction of long-term object representations.

23.305 **Reduced competition among contextually associated objects enhances detail memory for briefly glimpsed images** Nurit Gronau[1](nuritgro@openu.ac.il), Meytal Shachar[1]; [1]Department of Psychology, The Open University of Israel

What do we remember from an extremely brief snapshot? Typically, the 'gist' of a scene is grasped while relatively little visual detail is perceived and retained in long-term memory. Here, we investigated whether contextual and/or functional associations among objects may reduce stimulus competition and enhance long term memory of visual details when images are merely glimpsed. Participants viewed pairs of contextually-related and unrelated objects (e.g., a kettle and a mug; a shovel and a vase, respectively), presented for an extremely short exposure duration (24 ms, masked). Subsequently, participants performed a memory-recognition test, in which one of two objects within a pair was replaced by a novel object from the same basic category. Participants differentiated old objects from novel object exemplars, while these were presented with their original counterpart pair object. Results demonstrated higher levels of correct recognition for contextually-related than for unrelated object pairs. Furthermore, when object stimuli in the recognition test appeared alone, i.e., without a corresponding pair object serving as a memory-retrieval cue, results remained virtually identical. Namely, memory for specific visual details remained higher for objects initially appearing within contextually-related, than unrelated, object pairs. Finally, the nature of memory enhancement for contextually/functionally related object pairs was examined. Previous research has suggested that objects which are associated by action relations are particularly bound to perceptual integration. Based on an independent survey in which participants rated the extent to which pairs of objects depicted action relations, we found a memory advantage for contextually-related relative to unrelated items regardless of active/passive contextual associations. Taken together, our results suggest that during an extremely brief visual glance, contextually associated stimuli benefit from reduced object-to-object competition. Consequently, stimuli are 'bound' within a unified representation, allowing enhanced encoding and memory of their gist as well as of their perceptual visual details.

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23.306 **Forgetting induced by recognition of visual images** Ashleigh Maxcey[1](AMMaxcey@manchester.edu), Geoffrey Woodman[2]; [1]Department of Psychology, Manchester University, [2]Department of Psychology, Vanderbilt Vision Research Center, Center for Integrative and Cognitive Neuroscience, Vanderbilt University

Retrieval-induced forgetting is a phenomenon in which a group of stimuli is initially learned, but then a subset of stimuli is subsequently remembered via retrieval practice, causing the forgetting of other initially learned associates. This phenomenon has almost exclusively been studied using linguistic stimuli. The goal of the present study was to determine whether our memory for simultaneously learned visual stimuli was subject to a similar type of memory impairment. Participants were shown real-world objects, then they practiced recognizing a subset of these remembered objects, and finally their memory was tested for all learned objects. We found that practicing recognition of a subset of items resulted in forgetting of other objects in the group. However, impaired recognition did not spread to new objects belonging to the same category. Our findings have important implications for models of memory and how our memories operate in real-world tasks, where remembering one object or aspect of a visual scene can cause us to forget other information encoded at the same time.

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23.307 **Does drawing skill relate to better memory of local or global object structure?** Florian Perdreau[1,2](florian.perdreau@paris-descartes.fr), Patrick Cavanagh[1,2]; [1]Laboratoire Psychologie de la Perception, Université Paris Descartes, Sorbonne Paris Cité, Paris, France, [2]CNRS UMR 8158, Paris, France

An accurate drawing must respect the overall shape as well as the relative positions of the depicted object's features, which define its structure. We previously found that participants who are more skilled at drawing are also better at integrating structural information across eye-movements in a possible vs impossible objects task (Perdreau & Cavanagh, 2013). This ability may be due to an internal representation that is robust to the disruptions from the many eye-movements made between the object and the drawing. It remains unclear, though, whether drawing accuracy relates to the storage of the entire object's structure or only of the local features relevant to the current drawing position. To test these alternatives, we designed an interactive pen tablet experiment coupled with a delayed change detection task. A simple polygonal shape was displayed on a screen and participants had to copy it on a pen tablet on which they could see their drawing. At an unpredictable moment during the copying process, the drawing and the original shape were blanked out. After a fixed delay of 900 ms, the drawing reappeared with a possible modification consisting in the displacement of one of its vertices chosen relative to the last drawn point (n, n-1, n-2 or n-4). Participants had to report whether a modification in their drawing had occurred or not (2-AFC). Our results showed that participants who were more skilled at drawing were also better at detecting changes but only when these occurred either at the n (current) or at the n-1 position. This suggests that participants who were more skilled at drawing depended more on visual memory for the information relevant to the current drawing position and less on the memory of the object's global structure.

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23.308 **Constructing Gestalt in Visual Working Memory** Mowei Shen[1](mwshen@zju.edu.cn), Qiyang Gao[1], Ning Tang[1], Rende Shui[1], Shulin Chen[1], Zaifeng Gao[1]; [1]Xixi Campus, Zhejiang University, Hangzhou, China

So far ample studies have demonstrated that VWM plays a critical role in several fundamental cognitive processes, such as perception, language processing, and planning. A critical factor that makes VWM so important is that VWM could "actively" maintain and manipulate the incoming information. However, so far most of the studies focus on a relatively "static" aspect of VWM, for instance, capacity, representation resolution, etc. Few studies have attempted to explore the active aspect of VWM. Here we investigated the active part of VWM by asking whether a Gestalt could be constructed in VWM based on the incoming information. Particularly, in a modified change detection task, we sequentially presented the memorized objects. Importantly, in 50% of trials these objects could form a virtual rectangle or triangle (i.e., a Gestalt) when they were presented simultaneously. We predicted that if the VWM could actively hold the visual information, then it will detect the relationship among the objects and construct a Gestalt based on the stored objects, which will help reduce the memory load. In line with this prediction, in 5 experiments we consistently found that when a potential Gestalt could be constructed among the memorized 3 or 4 objects, VWM performance was significantly improved. These results suggest that VWM indeed is actively, instead of passively, involved in holding visual information.

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23.309 **Bringing the 'real-world' into cognitive science: real objects are more memorable than pictures** Taylor Coleman[1](taylorlc70@gmail.com), Rafal Skiba[1], Alexis Carroll[1], Scott Turek[1], Marian Berryhill[1], Jacqueline Snow[1]; [1]Department of Psychology, University of Nevada, Reno, Nevada USA

The overwhelming majority of research in the field of psychology has involved the study of 2-dimensional (2D) pictures of objects, rather than real-world exemplars. Recent evidence from neuropsychology, economic decision-making, and neuroimaging suggests, however, that real objects may be processed and represented differently than pictures. Here we examined the extent to which memory is influenced by the format in which objects are displayed. We tested the ability of undergraduate college students (n=86) to recall, and later to recognize, a set of 44 different common household objects. The objects in the study phase were displayed in one of three viewing conditions: real-world exemplars, colored photographs, or black and white line drawings. We used a between-subjects design in which observers were randomly assigned to one of the three viewing conditions. The order of stimulus presentation and timing was identical in each of the three conditions, and the photographs and line drawings were matched in size to the real objects. Both recall, and recognition performance, was significantly better for real objects than colored photographs or line drawings. There was no difference in memory for stimuli in either of the picture conditions. These results highlight the importance of studying real-world object cognition, and raise the potential for applied use in developing effective compensatory strategies for memory-related cognitive decline, and improving procedures for eye-witness identification.

23.310 **Through the fence or behind the wall: Occlusion type affects object memory** Karla Antonelli[1](karla.b.antonelli@gmail.com), Eumji Kang[1], Carrick Williams[1]; [1]Psychology, Mississippi State University

Real-world object memory representations are often visually incomplete due to occlusion. The current study explored whether different forms of occlusion influence visual memory representations and what differences in memory performance based on occlusion type could mean for visual memory representations that had been extracted. In two experiments, participants memorized 128 pictures of objects (one second presentation) that were 50% occluded with a multi-colored mask covering either a solid half of the object (solid condition), or stripes of the object that were equal in width and spacing across the object (stripe condition). The critical difference between the experiments was the form of the following memory test. In Experiment 1, a 2-AFC token discrimination memory test was used with the presented object token and a color-category matched foil token shown free of any occlusion. In Experiment 2, participants also performed a 2-AFC memory test, but chose between the exact presented image (including the occluding element) and the same object image but with a different portion of the object occluded/visible. For Experiment 1, memory accuracy for the solid (61%) and stripe (59%) conditions did not differ significantly for determining which object token had been presented. However, in Experiment 2, memory accuracy was significantly different between solid (64%) and stripe (54%) conditions in determining which portion of the object had been previously seen. The differences in memory performance imply that for the stripe condition, participants encoded more abstract representations of the occluded objects either "filling in" or "glossing over" the missing details. In contrast, the encoded representations in the solid condition appear to be less abstract emphasizing the exact portions of the object seen. Thus, even when equal portions of an object are visible, the occlusion form will affect how the object is remembered.

23.311 Emotional faces in visual working memory are not easily forgotten: Distractor effects on memory-guided visual search

Risa Sawaki[1](r.sawaki@bham.ac.uk), Jane Raymond[1]; [1]University of Birmingham, UK

Visual search is typically guided by goals that are represented in working memory. Here we ask whether recently encoded but to-be-forgotten emotional information can also bias visual search. Although it has been demonstrated that angry faces are better maintained in visual working memory than happy faces, it remains unknown whether they are more difficult to forget. The present study investigated this issue by monitoring eye movements while participants performed a memory-guided visual search task. In the task, participants first encoded and then maintained two faces (different identities with different emotional expressions: happy, angry, or neutral) in working memory. Then, part way through a 3 second retention interval, a cue was presented to indicate which face to continuously maintain as target and which to forget. Finally, participants searched for the target face among an array of six faces comprised of each of the previously presented identities expressing each possible emotion. We found that fixations on the search array item matching the to-be forgotten (TBF) distractor (TBF identity plus TBF emotion) were infrequent, short in duration, and did not depend on the TBF emotion (angry, happy). However, fixations on the distractor face that combined target identity with the TBF emotion were significantly longer when the TBF emotion was angry versus happy. This finding suggests that representation of an angry expression is difficult to suppress from visual working memory and that such information can subsequently influence visual search.

23.312 Feature as the basic storage unit of visual working memory

Benchi Wang[1,2](wangbenchi.swift@gmail.com), Zhiguo Wang[1]; [1]Center for Cognition and Brain Disorders, Hangzhou Normal University, China, [2]Department of Education, Zhejiang Normal University, China

Visual-working-memory (VWM) is crucial for complex cognitive tasks, such as learning and reasoning. Previous studies suggest that VWM stores integrated object, rather than independent features (Luck & Vogel, 1997). Memory accuracy is the same whether the participant needs to maintain one or all features from the same object. Several recent studies, however, have challenged this theory by demonstrating that features from the same object can be stored independently in VWM (Fougnie & Alvarez, 2011). Using change detection task (CDT), six experiments were conducted to resolve this controversy. Experiments 1-3 allocated two colors to either two or six to-be-remembered objects, whose identity was defined by color and shape (and/or location). The object-based theory predicts worse CDT performance when the number of to-be-remember objects was six. Experiments 1-3, however, consistently showed that CDT performance was unaffected by the number of to-be-remembered objects, even when possible perceptual grouping was precluded (Exp. 3). Experiments 4 and 5 further showed that this observation could be generalized to other feature dimensions (spatial frequency and orientation). One might suggest that this observation was obtained because only task-relevant features (e.g., color) were stored in VWM. To rule out this possibility, Experiment 6 was modified as following: a) Changes could happen to all object-defining features (color and orientation); and b) The to-be-remembered objects had two values from one feature dimension, whereas the number of feature values from the other dimension was the same as the number of the to-be-remembered objects. Replicating previous findings, the overall CDT performance declined as the to-be-membered objects increased from two to six. However, this decrease was mainly attributed to changes in the feature dimension with six values. This behavioral dissociation suggests that feature-binding did not happen and strongly support the theory that the units of storage in VWM are features, rather than objects.

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23.313 Feature and object representations in visual working memory are subject to top-down control

Amanda E. van Lamsweerde[1](amanda.vanlamsweerde@ndsu.edu), Jeffrey S. Johnson[1]; [1]North Dakota State University

Visual working memory (VWM) has a capacity limit of about 3-4 items; this limit is generally thought to operate on the level of an object (Luck & Vogel, 1997). However, it is also possible to group across objects of similar color (Peterson & Berryhill, 2013). We examined whether use of object and feature-grouping representations is constrained by top-down control. Participants viewed colored shapes and detected changes to: color-only, shape-only, or color-or-shape (either). Within a display, all of the features were unique (e.g., never two blue objects) or some of the features would be repeated. Detecting a single change type made the non-changing feature task-irrelevant, encouraging feature-grouping representations. However, detecting either change type should encourage participants to remember all of the features of an object, facilitating object-based representations. When detecting single change type (color-only or shape-only), performance was better when features were repeated than when they were unique. This indicates that identical colors and shapes can be grouped together in VWM. In addition, for both unique and repeated displays, performance was better at set size 3 than set size 4 (a typical set size effect); however, for color changes, performance for set size 4 - repeated features was equal to performance for set size 3 - unique features. Grouping by color may be so robust that adding an additional object to the 'grouped' representation incurs no additional cost to VWM capacity. However, when detecting either type of change within a block, there was no repetition advantage. Therefore, remembering both features of an object encouraged participants to remember features within an object together, rather than grouping features across objects. Therefore, not only can visual information be represented both as objects and feature groupings, but the use of each strategy can be modulated by top-down control.

23.314 The contribution of attentional lapses to estimates of individual differences in working memory capacity.

Irida Mance[1](iridam@uoregon.edu), Kirsten Adam[1], Keisuke Fukuda[2], Edward Vogel[1]; [1]Department of Psychology, University of Oregon, [2]Department of Psychology, Vanderbilt University

Individuals with low memory capacity perform poorly on fluid intelligence and attentional control tasks. Here, we examined whether low working memory performance is due to a reduced capacity, or if it is instead due to more frequent states of general inattention during the task. We used a whole report visual memory procedure and defined attentional lapses as trials in which individuals reported only one or fewer items correctly. Lower capacity individuals, as measured with a change detection task, had an average of 12.1% lapse trials, while high capacity individuals had 7.4% lapses. Thus, while low capacity individuals had more frequent states of inattentiveness, this factor did not account for all of the differences between them and their high capacity counterparts. Further, while all subjects lapsed more frequently for supra capacity arrays, low capacity individuals showed a much greater increase in inattentiveness during these trials. In a followup experiment, we examined whether this increase in lapses for large arrays was due to the high memory load or if it was due to an increased demand for attentional control. In one condition, subjects were shown arrays of 6 items and were precued to remember only a subset of the items, which allowed us to separately manipulate the memory load from the need to exert attentional control within the trial. Lapse frequency was high when subjects needed to exert attentional control irrespective of the number of items to be remembered, suggesting that the increase in lapses for large arrays was due attentional control demands rather than the memory load. Together, these results reveal that some, but not all, of the differences in performance between high and low capacity individuals are determined by the frequency of lapse trials, and this contribution is magnified under circumstances that require attentional control.

23.315 **Trial-by-trial fluctuations in working memory performance predict individual differences in working memory capacity**

Kirsten Adam[1](kadam@uoregon.edu), Irida Mance[1], Keisuke Fukuda[2], Edward Vogel[1]; [1]University of Oregon, [2]Vanderbilt University

Visual Working Memory (VWM) is commonly characterized using a change detection task (Luck & Vogel, 1997), but change detection errors reveal little about trial-by-trial performance. That is, errors produced on high-success trials (many items remembered) and low-success trials (no items remembered) are indistinguishable. Here, we employ a discrete whole-report task to precisely track trial-by-trial VWM performance. In the discrete whole-report paradigm, participants view a briefly presented array of colored squares. After a brief retention interval, colored grids appear at the locations of all items. Participants report the color of all items by clicking the color in each grid that corresponds with the remembered color. In Experiment 1, participants completed a change detection task (set sizes 2-6) and a whole-report task (30 trials each of set sizes 2-6). In Experiment 2, participants completed a change detection task (set sizes 4, 6, & 8) and 300 trials of whole-report (set size 6 only). The mean number of correct items in the whole-report task strongly corresponded with change detection capacity (Exp 1: $R2 = .52$, $p = <.001$; Exp 2: $R2 = .43$, $p = <.001$). Additionally, proportions of low-performance (<3) and high-performance (> 3) whole-report trials predicted VWM capacity. However, the majority of both high- and low-capacity subjects correctly identified a modal number of 3 items, and the proportion of whole-report trials with 3 items correct did not predict individual differences in VWM capacity. The present results reveal that precise characterization of high- and low-success trials has important and surprising implications for models of VWM. In particular, these results provide evidence that stable individual differences in VWM capacity should be be conceptualized as differences in successfully utilizing memory resources rather than as differences in total resources available.

23.316 **Spatial Working Memory in Children With High-Functioning Autism: Intact Configural Processing But Impaired Capacity**

Yuhong V. Jiang[1](jiang166@umn.edu), Christian G. Capistrano[1], Bryce E. Palm[1]; [1]Department of Psychology, University of Minnesota

Visual attention and visual working memory exert severe capacity limitations on cognitive processing. Impairments in both functions may exacerbate the social and communication deficits seen in children with an autism spectrum disorder (ASD). This study characterizes spatial working memory and visual attention in school-age children with high-functioning autism. Children with ASD, and age, gender, and IQ-matched typically developing (TD) children performed two tasks: a spatial working memory task and an attentive tracking task. Compared with TD children, children with ASD showed a more pronounced deficit in the spatial working memory task than the attentive tracking task, even though the latter placed significant demands on sustained attention, location updating, and distractor inhibition. Because both groups of children were sensitive to configuration mismatches between the sample and test arrays, the spatial working memory deficit was not because of atypical organization of spatial working memory. These findings show that attention and working memory are dissociable, and that children with ASD show a specific deficit in buffering visual information across temporal discontinuity.

Acknowledgement: University of Minnesota

23.317 **The relationship between vividness of visual imagery and indirect size-measurements of the visual cortex**

Kang Yong Eo[1](gazz11@empal.com), Oakyoon Cha[1], Yaelan Jung[1], Sang Chul Chong [1,2]; [1]Graduate Program in Cognitive Science, Yonsei University, [2]Department of Psychology, Yonsei University

Visual perception and imagery are known to use the same resources in the visual cortex (Kosslyn et al., 1995). The finding that the size of V1 predicts the amount of illusion (Schwarzkopf et al., 2010), which is part of visual perception, led us to postulate that the size of visual cortex is related to the vividness of visual imagery. In this study, the size of visual cortex was indirectly measured by vernier acuity and the size of the blind spot. Note that vernier acuity indicates the degree of cortical magnification (Duncan & Boynton, 2003) and the size of the blind spot reflects the size of optic nerve (Jonas et al., 1991). Vividness of imagery was measured by the vividness of visual imagery questionnaire (VVIQ; Marks, 1973). Results showed that the two indirect measurements were significantly correlated ($r=.273$, $p=.019$), and that VVIQ scores were also significantly correlated with vernier acuity ($r=.295$, $p=.011$) and also with the size of the blind spot ($r=.384$, $p=.001$). These correlations indicate that vivid imagers (having lower VVIQ scores) are related to smaller size of visual cortex, suggested by the indirect measures. VVIQ-defined vivid imagers can be characterized by their faster generations of visual imagery as reported by D'Angiulli and Reeves (2002). To test this hypothesis, we measured the time taken to generate the image of each question in VVIQ for 39 out of 83 participants. Results showed that as generated images became more vivid, the time taken to generate them was shorter ($r=.445$, $p=.005$). This positive relationship was further supported by the significant result that the number of participants who showed positive correlations between the two variables was more than that of those who did not ($x^2(1)=39$, $p<.001$). In sum, vivid imagery was correlated with faster imagery, which might have been enabled by smaller visual cortex.

Acknowledgement: This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MEST) (2011-0025005)

Perceptual organisation: Neural mechanisms and models

Saturday, May 17, 8:30 am - 12:30 pm
Poster Session, Jacaranda Hall

23.318 **EEG frequency-tagging yields a neural signature of integration of parts into perceptually organized wholes**

Nihan Alp[1](nihan.alp@ppw.kuleuven.be), Naoki Kogo[1], Goedele Vanbelle[2], Johan Wagemans[1], Bruno Rossion[2]; [1]Laboratory of Experimental Psychology, University of Leuven, Leuven, Belgium, [2]Institute of Research in Psychology and Institute of Neuroscience, University of Louvain, Louvain la Neuve, Belgium

How does a holistic representation arise in the visual system? Although this question has been under investigation for more than hundred years since Wertheimer's seminal work, it is still unclear how the visual system integrates the parts of an object into a whole representation. The general intuition from Gestalt psychology has been that the whole-based activation requires non-linear interactions between the parts but current methods have not been able to pinpoint exactly what they are. Here we applied high-density electroencephalography (EEG) in combination with the technique of frequency tagging (Regan & Heron, 1969) to define an objective trace of a Gestalt in the visual system. Specifically, by using the Kanizsa square figure, we tracked the emergence of an illusory surface. In the "experimental condition", four pacmen were placed to form an illusory square. In the "control condition", the four pacmen were rotated away so that the illusory surface disappeared. The two diagonal pacman pairs were 100% contrast-modulated at different frequency rates ($f1= 3.57$ and $f2= 2.94$ Hz) for 13 seconds. Fourier transform of the EEG recordings (12 participants) showed robust low-level responses specifically at these fundamental frequency rates, which did not differ between conditions. Most importantly, strong nonlinear intermodulation (IM) components (e.g., $3.57-2.94=0.63$ Hz) appeared in response to the illusory figure. These IMs can only be produced by neuronal populations that integrate the two stimulations nonlinearly (e.g., Boremanse et al., 2013), and they were only present in the experimental condition where all the parts (pacmen) are integrated coherently to form an illusory surface. Moreover, changing the support ratio influenced the amplitude and the distributions of IMs, but not the fundamental frequencies. These results indicate that IM components in EEG provide a neural signature of Gestalt configurations.

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23.319 **Competition-based ground suppression in extrastriate cortex and the role of attention**

Laura Cacciamani[1](lcacciam@email.arizona.edu), Paige E. Scalf[1], Mary A. Peterson[1,2]; [1]Psychology Department, University of Arizona, [2]Cognitive Science Program, University of Arizona

Theories of object perception posit that regions sharing a border compete for object status. The winner is perceived as the object, the loser as a shapeless ground. Previous research showed that neural representations of the ground are suppressed. Experiment 1 used fMRI to search for evidence that the amount of ground suppression varies with the amount of competition. Participants performed an RSVP task at fixation while task-irrelevant, novel silhouettes appeared in the upper left (LVF) or right visual field (RVF). Unbeknownst to participants, the silhouettes differed in whether well-known or novel objects were suggested on the groundsides of their borders (high- and low-competition silhouettes, respectively). We expect more suppression on the groundsides of the former than the latter. Results showed significantly less activation on the groundsides of high- vs. low-competition silhouettes in V4 and V2 ($p<.05$), which we interpret as greater ground suppression under conditions of greater competition. This effect was only observed for RVF/left hemisphere (LH) presentation. One explanation of this laterality effect is that more attention is captured by RVF than LVF stimuli. Experiment 2 tested this hypothesis by

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assessing whether conflict stimuli in the RVF draw more attention away from the RSVP task. A high- or low-competition silhouette appeared (RVF or LVF) on each trial while participants performed an RSVP task at fixation. RSVP performance was reduced when high- vs. low-competition silhouettes appeared in the RVF but not in the LVF (p<.05), suggesting that attention is indeed captured more by stimuli in the RVF than LVF. Experiment 1 provides neural evidence for competition-based ground suppression. Given our large displays (4o high), the V2 suppression is likely mediated by feedback from higher levels with larger receptive fields. Experiment 2 suggests that attention may be needed to resolve this competition. The precise role of attention remains to be elucidated.

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23.320 **Decoding orientation of visual stimuli from human magnetoencephalography data** Radoslaw Cichy[1], Dimitrios Pantazis[2]; [1]Computer Science and Artificial Intelligence Laboratory, MIT, Cambridge, MA, [2]McGovern Institute for Brain Research, MIT, Cambridge, MA

Local orientation is a fundamental feature extracted by visual perception. Recent advances in multivariate analysis methods in fMRI have allowed the direct and non-invasive localization of orientation encoding in the human brain, but have left its temporal aspects unclear. Here, using magnetoencephalography (MEG) we resolve with high temporal resolution the time course of orientation encoding. In experiment 1, participants observed sinusoidal gratings tilted 45° to the right or left from vertical. In experiment 2, sinusoidal gratings were oriented from 0 to 150° in 30° steps; and in experiment 3, they were radially balanced exponential spirals oriented 45° to the right or left. All stimuli were shown in two different phases (phase and anti-phase) to allow dissociation of orientation from local luminance differences. We used time-resolved multivariate pattern classification (support-vector machines) to decode the observed orientation from MEG data. In all three experiments and for all orientations, we find robust and significant decoding starting at ~65-70ms after stimulus onset. In addition, experiment 2 shows that orientation decoding is not merely due to a radial bias in the representation of orientation. Comparing decoding for oblique vs. cardinal orientations (experiment 3), we find only weak evidence for a cardinal bias as a factor in orientation decoding in MEG. Importantly, results were independent of the local luminance of the stimuli, i.e. they generalized across phase. Our results demonstrate that multivariate analysis of MEG signals allows content-sensitive and direct read-out of local visual orientation information, and inform about the factors enabling orientation decoding.

Acknowledgement: Thanks to Aude Oliva for providing additional support for this work Humboldt Foundation scholarship to R.C. Volkswagen Foundation grant to R.C. Data recorded at the Athinoula A. Martinos Imaging Center at McGovern Institute for Brain Research, MIT.

23.321 **A Meta-analysis of Multi-voxel Patterns in the Ventral Stream** Marc N Coutanche[1](coumarc@psych.upenn.edu), Sarah H Solomon[1], Sharon L Thompson-Schill[1]; [1]Department of Psychology, University of Pennsylvania

Over the past decade, hundreds of scientific papers have attempted to decode the multi-voxel patterns underlying distinct perceptual and cognitive states. For the multi-voxel pattern investigator, a large number of methodological decisions are required, many of which can impact classification results. We present a meta-analysis, with two goals: 1.) To discover and quantify various influences on pattern detection from results across many studies, and 2.) To determine the neural regions implicated in representing different types and classes of visual entities. We collected all peer-reviewed papers from Google Scholar, PubMed, Web of Science, and Scopus that either included relevant sear-terms (e.g., "MVPA", "classification"), or cited a seminal study by Haxby et al. (2001). We employed inclusion criteria to reduce this set to papers examining multi-voxel patterns for visual items in the occipital and/or temporal cortices of healthy adults. By coding these papers on a series of method-related variables (e.g., voxel resolution, experimental design, classification technique), brain-related variables (e.g., region), and classification results, we can predict and then test which variables influence multi-voxel pattern discriminability, and quantify their influence. For example, within the set of method variables, classification accuracy is improved with a greater number of acquisition runs. Within the brain-related variables, patterns become less discriminable from posterior to anterior retinotopic regions. This meta-analysis will provide a comprehensive summary of the relevant published research, and also point to various methodological variables that can help or hinder attempts to decode neural representations in the human brain.

23.322 **Case study of unexplained visual field loss and perceptual deficits in the presence of normal early visual function** Christina Moutsiana[1](christina.moutsiana@gmail.com), Radwa Soliman[1], Lee de-Wit[2], Martin I. Sereno[1], Gordon Plant[3,4], D. Samuel Schwarzkopf[1]; [1]Division of Psychology and Language Sciences, University College London, [2]Experimental Psychology, KU Leuven , [3]Dept. Neurology, Institute of Neurology, University College London, [4]National Hospital for Neurology and Neurosurgery, University College London Hospitals

Previous work on patients with visual cortex lesions has shown that some visual function can be preserved in the absence of conscious perception. Here we present a patient (female, 50yrs) with monocular vision since 8 years old because of tumor in the other eye. She shows unexplained visual field loss and deficits in visual perception in the absence of any evidence of structural damage to the early visual pathway or lesions in visual cortex. Perimetry demonstrated severe anopia of the lower visual field and a clockwise progression of the loss through the upper left visual field over several years. Behavioral and functional magnetic resonance imaging data were collected during two visits, one year apart. The patient and three healthy controls viewed moving wedge and ring stimuli for retinotopic mapping while images were acquired in a Siemens Avanto 1.5T MRI scanner. We performed population receptive field (pRF) analysis to map the functional organization of visual cortex. Despite the visual field loss, the patient's retinotopic maps and pRF parameters in occipital cortex were qualitatively normal. Control analyses confirmed that this was not an artefact of pRF analysis methods. Additional behavioral data confirmed the perimetry results using identical stimuli as used for retinotopic mapping: the patient could only detect stimuli presented in the upper right visual quadrant. The patient did not show evidence of blindsight. Furthermore a severe deficit in perceptual grouping and integration was revealed using the Leuven Perceptual Organisation Screening Test (L-POST) while simple visual ability was relatively preserved. Taken together, our findings suggest that apparently normal functional organization of visual cortex does not guarantee conscious perception across the visual field.

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23.323 **Increased alpha band activity indexes inhibitory competition across a border during figure assignment** Joseph L. Sanguinetti[1, 2](sanguine@email.arizona.edu), Logan T. Trujillo[3], David M. Schnyer[3], John J. B. Allen[1, 2], Mary A. Peterson[1, 2]; [1]Psychology Department, University of Arizona, [2]Cognitive Science Program, University of Arizona, [3]Psychology Department, University of Texas, Austin

Prior research shows that increased activity in the alpha band of the EEG may index inhibition of competing information when covert attention is directed to one hemifield and the distracting stimulus is in the other. Here we tested whether increased alpha activity indexes inhibitory competition for figural status. Across 3 experiments, participants viewed real world or novel silhouettes and made "real-world/novel" judgments. Real world silhouettes (n = 40) depicted namable objects. There were two types of novel silhouettes; both depicted novel objects on the inside of their borders. Low competition silhouettes (n = 40) suggested novel objects on the outside of their borders as well. High competition silhouettes (n = 40) suggested portions of real-world objects on their outside, groundside; critically, participants saw the inside as figure and were unaware of the suggested real-world objects on the groundside. Nevertheless there is more cross-border competition for figural status in high- versus low-competition silhouettes. With more competition there should be more inhibition of the object suggested on the groundside. Therefore we predicted an increase in alpha power for high- versus low-competition silhouettes. In Experiment 1, each silhouette was presented once within a single block (4 blocks total). In Experiment 2 single repetitions occurred within 18-21 intervening items within a single block. In these experiments we found increased alpha power in the predicted direction (p <.05) collapsing across repetitions. Experiment 3 used shorter lags (4-7 intervening items). Here alpha power was reduced for second versus first presentation of high competition silhouettes only (p <.05), suggesting that inhibition of the object suggested on the groundside persists for a short time and reduces competition on the second presentation. These results demonstrate for the first time that increases in alpha activity can be used to measure inhibitory competition across a border during figure assignment.

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23.324 **Direct neurophysiological measurement of surround suppression in humans** Marta Isabel Vanegas-Arroyave[1](martaisabelv@gmail.com), Annabelle Blangero[1], Simon Kelly[1]; [1]Department of Biomedical Engineering, The City College of The City University of New York, New York NY

Surround suppression is a well-known example of contextual interaction in visual cortical neurophysiology, whereby the neural response to a stimulus presented within a visual neuron's classical receptive field is suppressed by the presence of surrounding contrast. Human psychophysical reports present an apparent analog to these single-neuron effects: stimuli appear lower-contrast when embedded in a surround. Surprisingly, surround suppression effects have not been demonstrated in human electrophysiology to bridge between perceptual reports and neuronal responses. We recorded electroencephalography (EEG) in sixteen subjects while passively viewing a series of full-screen stimuli, in which a "foreground" stimulus of different contrasts flickered over various static "surround" patterns. The flickering foreground elicits a steady-state visual evoked potential (SSVEP) over posterior scalp, from where we derived corresponding contrast response functions. We tested both parallel and orthogonal surrounds, both peripheral and foveal foregrounds, and both low and high flicker frequencies (7.2Hz and 25Hz). Using the same flickering stimulus, participants also performed a psychophysical matching task in which an isolated foreground (match, varying contrast) was compared to a surround-embedded foreground (test, fixed at 50% contrast). We demonstrate marked suppression of the foreground response which scales with the contrast of the surround. In keeping with both human psychophysics and animal neurophysiology, we found that suppression was stronger for surrounds that matched the foreground in orientation, and for peripheral compared to foveal foregrounds. This pattern was reproduced in psychophysical reports of perceived contrast in the same individuals, and the degree of electrophysiological and psychophysical suppression was correlated across subjects. Analysis of amplitude changes over time revealed effects of short-term contrast adaptation, which variously caused the foreground signal to fall or grow over time depending on the relative contrast of the surround contrast, consistent with steeper adaptation of the suppressive drive.

23.325 **Ventral and dorsal streams in cortex: focal vs. ambient processing/exploitation vs. exploration** Bhavin Sheth[1,2](brsheth@uh.edu), Ryan Young[3]; [1]Department of Electrical & Computer Engg, University of Houston, [2]Center for NeuroEngineering and Cognitive Science, University of Houston, [3]Rice University, Houston, TX

The idea of a dissociation of the visual pathway into two distinct streams—ventral and dorsal—that each processes distinct kinds of information is a powerful one. Two proposals along those lines state that the ventral stream processes information about object identity ("what"), whereas the dorsal stream processes information about either object location ("where"; Ungerleider & Mishkin, 1982;) or to perform motor acts ("how"; Goodale & Milner, 1992). Both proposals are influential but contradicted by recent data (e.g. ventral stream is involved in where/how computations; the dorsal stream is involved in "what" computations). We suggest a more robust dichotomy breaking down into 1. a ventral stream sampling high-resolution/focal spaces, and therefore, macularly-biased, and 2. dorsal ambient sampling, and therefore less spatially biased streams. This dichotomy may derive from pressures exerted during evolution by dense receptive surfaces. The idea further hews more closely to the theme of embodied cognition: Function arises as a consequence of an extant sensory underpinning. A continuous, rather than sharp, segregation based on function emerges, and carries with it an undercurrent of an exploitation-exploration dichotomy. Under this interpretation, cells of the dorsal stream, which individually have large receptive fields and poor spatial localization, do not provide information about location but rather of the presence/absence of salient objects in the visual field for exploration. Our model is not exclusive to the primate/hominid visual system but is extendable to the bat auditory system and could provide an evolutionary basis for the development of the fovea and mechanisms for eye tracking in animals. We leverage our dichotomy to explain neuropsychological cases (visual agnosia, optic ataxia), account for the prevalence of multisensory integration in the dorsal rather than the ventral stream under a Bayesian framework, and provide a dynamic component to the ventral-dorsal dichotomy that helps create a unified, seamless perception.

23.326 **Anatomically-driven Visual Neural Model Assessments Predict Temporal Thresholds Associated with the Dorsal and Ventral Systems** Steven R. Holloway[1](srh@asu.edu), Michael K. McBeath[1]; [1]Arizona State University

An abundance of evidence supports functional anatomical specialization of cortical visual pathways. This suggests that we should be able to measure the functional processing characteristics of a specific neural pathway by emphasizing the characteristics of a stimulus that corresponds to known response characteristics of that system and by limiting those stimulus characteristics not related to the system in question. Using neural pathway models that specify distinct and measurable stimulus characteristics as a guide, we created classes of stimuli that varied in shape, presentation speed, relative brightness, edge distinctiveness, and color. This allowed us to develop and test several within-subject objective measures that are associated with recent neural anatomical models of dorsal and ventral visual pathways that predict distinct levels of temporal information processing. In the first study, baseline flicker thresholds were compared against a shape-recognition task that targeted ventral stream processing and against an apparent motion measure that targeted dorsal stream processing . For both tests, we developed objective measures in which participants identified the correct directionality of stimulus change. We found that thresholds for shape recognition were significantly slower than those for apparent motion, supporting the contention that the shape-assessment measure was consistent with ventral processing and distinct from dorsal processing. The second study compared a shape-defined-by-motion recognition task across ten speeds and three colors. We predicted three levels of temporal processing corresponding to each color condition and compared performance with a static control that presented the same information and conditions but without motion. Thresholds for shape recognition differed significantly by color and matched predicted levels of performance. Furthermore, crossover points between motion and static control conditions exhibited a consistency despite differences in shape-recognition performance. Overall, our findings support the contention that the two visual systems have distinct temporal processing rates but share information at a higher cortical level.

23.327 **A bidirectional link between neuronal oscillations and geometrical patterns** Federica Mauro[1, 2, 3](federica.ma@gmail.com), Antonino Raffone[3], Rufin VanRullen[1,2]; [1]Université de Toulouse, Centre de Recherche Cerveau et Cognition, Université Paul Sabatier, 31062 Toulouse, France, [2]CNRS, UMR 5549, Faculté de Medecine de Purpan, CHU Purpan, 31052 Toulouse Cedex, France, [3]Department of Psychology, University of Rome Sapienza, Via dei Marsi 78, 00183 Rome, Italy

A specific geometric stimulus pattern (a wheel) can resonate with oscillations and induce an illusory perception of flicker (Sokoliuk & VanRullen, Journal of Neuroscience, 2013). Conversely, a steadily flickering light is known to produce visual hallucinations of geometric patterns; the exact perceived pattern depends on the stimulation frequency. Presumably, the flicker entrains neuronal oscillations that in turn give rise to the geometric hallucination. In order to shed light on this interaction, we first mapped the relationship between the temporal frequency of flicker stimulation and the geometrical organization of illusory patterns reported by subjects. Then we reversed this relation, and measured the effects of actually viewing specific geometric shapes on ongoing EEG activity. 8 subjects observed a homogeneous visual field flickering at different frequencies from 3 to 40 Hz. At the end of each 100-s trial, they were asked to describe any hallucinatory pattern(s) experienced, and indicate its perceived vividness. The most reported shapes were wheels and spirals. Wheels were significantly more likely to occur (and more vivid) below 10Hz, whereas spiral hallucinations peaked between 10 and 20Hz. Then, based on these subjects' descriptions, we created prototypical pictures of a wheel and a spiral illusory percepts, and equalized their contrast and 2D Fourier power spectra. We presented the two static pictures (in randomly interleaved 12-s trials) to a distinct group of 11 subjects undergoing EEG recording. The EEG power spectra associated with the two patterns showed significant differences over occipital and parietal electrodes. Perception of the wheel evoked higher activity at EEG frequencies below 10Hz, while the spiral evoked significantly higher EEG activity between 10 and 20Hz. We conclude that the link between neuronal oscillations and geometric patterns is bidirectional: flicker stimulation induces frequency-specific geometric hallucinations, and the same statically presented geometric shapes selectively enhance the same brain oscillatory frequencies.

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23.328 **Modulation of orientation discrimination in artificial scotoma zone with transcranial direct current stimulation** Latifa Lazzouni[1](llazzouni@gmail.com), Dave Saint-Amour[1]; [1]Psychology department, Laboratoire d'electrophysiologie neurovisuelle, University of Quebec in Montreal

When looking at a dynamic texture, a circumscribed lack of visual information in the peripheral visual field tends to be filled with the surrounding pattern, a phenomenon that is associated with visual completion or filling-in of the artificial scotoma. The underlying mechanisms are thought to involve disinhibition, which yields to invading activity of hyper-excited neighbouring neurons into the deafferented area (scotoma). The present study took advantage of this phenomenon to investigate short-term plasticity in the human visual system. We first aimed to investigate the strength of the filling-in effect of a peripheral artificial scotoma by measuring orientation discrimination thresholds. Second, transcranial direct current stimulation (tDCS) was used to modulate filling-in effects by changing visual cortex excitability. Thirteen healthy participants (with normal or corrected vision) took part in the study. In the psychophysical experiment, 6 subjects had to decide whether a Gabor patch presented in the scotoma zone was tilted to the left or to the right from the vertical, under two conditions: the filling-in (conditioning) and control (no-conditioning) conditions. Orientation thresholds were obtained using a 1-up/2-down staircase procedure, and compared using t-tests. In the tDCS experiment (n=7) the task was repeated, but under online tDCS over Oz, either with anodal or sham. Both sessions were separated by at least 48 hours. A repeated-measure ANOVA was performed with factors Task (conditioning vs. no-conditioning) and Stimulation (anodal vs. sham). Results show a significant main effect of Task, such that thresholds during conditioning were higher than the control task, and this effect was increased by the anodal stimulation with a significant interaction between both factors. These preliminary results show that the filling-in of an artificial scotoma increases subsequent orientation thresholds in the inner scotoma zone. This filling-in effect, which is likely due to disinhibition and invading activity, can be influenced with tDCS.

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23.329 **Lateral interactions in schizophrenia: What is the role of spatial frequency?** Brian Keane[1,2,3](brian.keane@gmail.com), Sabine Kastner[4,5], Danielle Paterno[2], Genna Erlikhman[6], Steven Silverstein[1,2]; [1]Department of Psychiatry, Rutgers—Robert Wood Johnson Medical School, [2]University Behavioral Health Care, Rutgers University, [3]Center for Cognitive Science, Rutgers University , [4]Princeton Neuroscience Institute, Princeton University, [5]Department of Psychology, Princeton University, [6]Department of Psychology, University of California, Los Angeles

Introduction. According to recent behavioral studies, people with schizophrenia are poor at filling-in between collinear elements because of impaired long-range horizontal connections in early visual cortex. However, patients also poorly process low spatial frequencies (SFs), which is thought to arise from dysfunction along the magnocellular pathway. In this study, we aimed to replicate the finding of impaired lateral interactions in schizophrenia and also to determine whether such impairments can be improved by employing high SF elements. Method. We had 24 persons with schizophrenia and 25 well-matched controls repeatedly detect a low-contrast element flanked by collinear or orthogonal high-contrast elements. An up/down staircase governed the contrast of the central target so that subjects detected the target 79.4% of the time. The three element display (target + flankers) was scaled in size to produce a lower and higher spatial frequency condition (4 and 10 cycles/deg, respectively). Results. Contrast thresholds were lower in the collinear than the orthogonal condition ($p<.000001$), indicating a robust collinear facilitation effect. Somewhat surprisingly, the effect did not depend at all on subject group ($p=.62$). There was a marginal three way interaction ($p=.07$) such that collinear facilitation in the clinical group tended to strengthen (relative to controls) at the lower SF, which was opposite to what we predicted. Interestingly, increased levels of conceptual disorganization among patients correlated with weaker collinear facilitation ($p<.05$), which fits with findings from other perceptual organization tasks. Conclusion. These results indicate that—in schizophrenia—lateral interactions are intact and do not weaken at lower SFs. At the same time, patients with disorganized thinking are worse at perceptual organization, though it remains unclear whether this effect originates in early visual areas.

Acknowledgement: F32MH094102

23.330 **Testing the Stationary Variability Assumption in Signal Detection Theory** Carlos Cabrera[1](cabrera.36@osu.edu), Zhong-Lin Lu[1], Barbara Dosher[2]; [1]Laboratory of Brain Processes (LOBES), Department of Psychology, The Ohio State University, [2]Memory, Attention and Perception Laboratory (MAPL), Department of Cognitive Sciences and Institute of Mathematical Behavioral Sciences, University of California, Irvine

Signal Detection Theory (SDT; Green and Swets, 1966) is possibly the most successful theoretical framework in cognitive psychology and features prominently in a variety of other research, clinical, and applied settings. Investigators frequently invoke SDT to estimate sensitivity and response bias by inferring observers' internal representations of stimuli using the z-transformed receiver operating characteristic (zROC). The zROC analysis assumes stationary distributions of internal representations at different criteria along the decision axis. Here we develop a procedure to test this assumption with a multi-pass paradigm (Burgess & Colborne, 1988; Green, 1964) in which subjects respond to multiple presentations of identical stimuli in order to estimate total variance in noise and signal+noise trials across different bias manipulations. We deployed this procedure in a multi-pass Yes/No visual detection experiment. Subjects responded 'Yes' or 'No' to stimuli consisting of a Gabor temporally combined with external noise (signal present) or external noise alone (signal absent). We estimated the total internal noise at three different bias manipulations: P[signal] = 70%, P[signal] = 50%, and P[signal] = 30%. Bias manipulations did not significantly alter mean signal strength, but did lead to significant differences in criterion placement and total internal noise. Changes in internal noise at different bias levels suggest that decision noise contributes to response variability and that this noise component depends on criterion position. We propose utilizing this multi-pass procedure at only a single, unbiased (P[signal] = 50%) condition to avoid altering underlying distributions with bias manipulations to provide a robust estimate of the ratio of the variability of the internal representations in noise alone and signal+ noise conditions. This procedure also avoids more costly and time consuming bias procedures, and sidesteps the varying decision noise of confidence ratings (Mueller & Weidemann, 2008; Wickelgren, 1968) or other criterion-dependent features of the internal representations (Balakrishnan, 1999).

Acknowledgement: MH081018

23.331 **A Bayesian observer model constrained by efficient coding accounts for both attractive and repulsive biases** Xue-Xin Wei[1,3](weixxpku@gmail.com), Alan Stocker[1,2,3]; [1]Department of Psychology, [2]Department of Electrical and Systems Engineering, [3]University of Pennsylvania

Bayesian observer models have been quite successful in accounting for perceptual behavior. However, it is a common challenge to specify the two fundamental components of a Bayesian model, the prior distribution and the likelihood function, because they are formally unconstrained. We argue that a perceptual system that is adapted to the statistical structure of its environment naturally imposes constraints on its corresponding Bayesian model description. In particular, we assume the prior to reflect the stimulus distribution and the likelihood to be constrained by a sensory representation that is efficient. We show that these assumptions lead to an observer model that makes two counter-intuitive predictions: First, perceptual biases can be repulsive (i.e. biased away from the peak of the prior), which is in stark contrast to the traditional Bayesian view. Second, the model predicts that neural and stimulus noise are differentially affecting perceptual bias, with larger neural noise leading to an increase in repulsive bias while larger stimulus noise leading to a decrease. We tested our model against reported experimental data regarding two perceptual variables for which the natural stimulus statistics are known (orientation and spatial frequency of visual stimuli). We found that the model predicts the reported repulsive biases from the cardinal orientations and low spatial frequencies, respectively. Furthermore, it also accounts for the observed increase in bias with increasing levels of neural noise, as well as the relative attractive bias when comparing stimuli with high versus low stimulus noise. The model is capable of making quantitative predictions up to a scaling factor for any perceptual variable for which the stimulus statistics are known. Our results suggest that efficient coding provides a powerful constraint in specifying Bayesian observer models, and leads to successful predictions of perceptual effects that have been considered incompatible with the Bayesian framework.

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23.332 **Computational Mechanisms Responsible for the Hermann Grid Illusion**
Rosemary Le[1](rosemary.le@stanford.edu), David Alex Mely[2], Thomas Serre[2]; [1]Psychology Department, Stanford University, [2]Department of Cognitive, Linguistics, and Psychological Sciences, Brown University

The Hermann grid is a well-known illusion. In its classical form, one perceives non-existent gray spots at the intersections of a white grid over a black background. Textbooks attribute the phenomenon to the center-surround organization of retinal ganglion cells. But in recent years, variations of the illusion have been created demonstrating that the center-surround organization cannot be the sole mechanism. While many qualitative theories have been proposed, no computational model has yet been shown to account for all variations. Here we consider several computational models of early vision including a baseline model of retinal ganglion cells, as well as increasingly more sophisticated models of the primary visual cortex (V1) that include divisive normalization, cardinal bias, and orientation-dependent lateral connections. We conducted a psychophysics experiment where participants (n=20) ranked multiple variations of the illusion according to their relative strength. Many of the variations used were created by researchers who previously studied this illusion. Together, the illusions ranged from non-existent to extremely strong. The average of the participants' rankings produced a ground truth against which model output rankings were compared. Spearman's correlation measured the consistency of the model's ranking to the ground truth. Model parameters were constrained by neurophysiologically data and optimized to best fit subjective illusion strength data. We find that the most complete model of V1 (which includes normalization, cardinal bias, and lateral connections) is the best predictor of human illusion perception when compared against simpler models. Our results thus confirm that the origin of the Hermann grid illusion is cortical in nature and that the relative strength of its variations appear to stem from the complex interaction of several well-established cortical processes.

Acknowledgement: This work is supported by NSF early career award (IIS-1252951), ONR (N000141110743) and the Robert J. and Nancy D. Carney Fund for Scientific Innovation. Additional support is provided by the Brown Institute for Brain Sciences (BIBS), the Center for Vision Research (CVR) and the Center for Computation and Visualization (CCV).

23.333 **Border-ownership computation reflecting consistency of surface properties**
Naoki Kogo[1](naoki.kogo@psy.kuleuven.be), Vicky Froyen[2]; [1]Laboratory of Experimental Psychology, University of Leuven (KU Leuven), Belgium, [2]Dept. of Psychology, Center for Cognitive Science, Rutgers University - New Brunswick, United States

Convexity preference is one of the factors that influence figure-ground organization. However, in certain conditions, the convexity preference can be suppressed and non-convex regions might be perceived as figural. It has been suggested that consistency of surface properties plays a key role for this reversal. For example, if a convex region is in the middle of another surface and has the same color/texture as the background, it is often perceived as a hole. The preference of convex regions in repetitive columnar configurations is also reduced if the concave regions have inconsistent colors (Peterson & Salvagio, 2008, Journal of Vision, 8(16), 4.1–13). Importantly, Zhou et al. (2000, Journal of Neuroscience, 20(17), 6594–6611) showed that many border-ownership (BOWN) sensitive neurons in V2/V4 were also sensitive to contrast polarity. Accordingly, Zhaoping (2005, Neuron, 47(1), 143–153) developed a model in which BOWN signals are enhanced when they are consistent in both the ownership and the contrast polarity. Inspired by her model, we first developed a simplified algorithm to compute BOWN that exhibit the convexity preference. It successfully reproduced illusory contour perception (DISC model, Kogo et al, 2010, Psychological Review., 117(2), 406–439). We, then, tested the performance of the model which also reflects the consistency of the surface colors at the location of the signals as in Zhaoping's model. We report that this approach gives extremely robust responses to various images with complexities both in shapes and in depth orders such as the examples mentioned above, suggesting the importance of this approach for BOWN computation. We further investigated, 1: the role of contrast insensitive BOWN signals, 2: the role of concavity preference algorithm, and 3: the effect of inhibitory connections. We will report how these factors affect the model's responses to reproduce figure-ground perception of complex figures.

Acknowledgement: Fund for Scientific Research Flanders (FWO)

23.334 **Normative Data for Forty, Morphing, Line Drawn Picture Sets**
Elisabeth Stoettinger[1](estoettinger@uwaterloo.ca), Nazanin Mohammadi Sepahvand[1], Nadine Quehl[1], James Danckert[1], Britt Anderson[1,2]; [1]University of Waterloo, Department of Psychology, [2]Centre for Theoretical Neuroscience, University of Waterloo

The updating of perceptual representations is important to a number of areas of psychology including the areas of set shifting, perserveration, theory of mind, perceptual learning, and our own interest in mental model updating. Many tasks that are used to detect such updating use simple stimuli such as motor sequences. When more complex stimuli are used it is often difficult to determine the importance of shifts, because normative data are not available. To better characterize how and when people update perceptual representations of ambiguous stimuli, we measured how people change their reports of percepts of line drawings that gradually morph (over 15 iterations) from one object to another. Here we present normative data for forty picture series that morphed from an animate to an inanimate object (or vice versa if shown in reverse order) or morphed within the animate and inanimate classes. When a participant goes from labeling an image sequence by the first label to a new label, an update to their perceptual representation can be inferred. The number of first image labels was used to measure of how long it takes participants to update. 178 participants labeled the pictures in our sets. Each set was rated by an average of 45 people (min =35, max = 65). On average participants updated from the first representation after 7 (± 0.91) pictures (min = 4.8, max = 9.7). Naming consistency for individual images ranged from 9 percent to 95 percent with a mean of 64 (± 21) percent. These picture sets are easy to administer and have been used within vastly different participant populations (3 and 5 year old children, healthy seniors, brain damaged persons). Given the perceptual simplicity these stimuli are also useful for EEG and fMRI studies.

Perceptual organisation: Contours and surfaces

Saturday, May 17, 8:30 am - 12:30 pm
Poster Session, Jacaranda Hall

23.335 **Properties of Spatiotemporal Boundary Formation**
Gennady Erlikhman[1](gennaer@gmail.com), Gideon Caplovitz[2], Philip Kellman[1]; [1]Department of Psychology, University of California, Los Angeles, [2]Department of Psychology, University of Nevada, Reno

Background: Spatiotemporal boundary formation (SBF) is the perception of contours, global form, and global motion from discrete transformations of sparse textural elements of which gradual accretion and deletion of texture is a special case (Shipley & Kellman, 1994, 1997). While some aspects of SBF are understood, little work has been done to uncover the underlying computational and neural mechanisms. Research Questions: What are the conditions (texture element and global shape transformations) that support SBF? How can the process be modeled? What are the neural mechanisms that support global shape perception in SBF? Design: We conducted several experiments in which transformations of sparsely distributed, circular texture elements or Gabor patches resulted in percepts of clear illusory boundaries and surfaces. An invisible, virtual object moved along a circular path in the display. Elements that fell within the boundary of the object changed color, position, or orientation. Virtual objects transformed in size, orientation, velocity, or shape. Texture element density was also manipulated. Subjects performed a 10-AFC task in which they matched the perceived object to one of 10 possible shapes. Results and Conclusions: Identification accuracy improved with increasing element density. SBF supported shape identification even for non-rigid, transforming virtual objects. All texture element transformations except for isoluminant color changes resulted in SBF, suggesting that the process depends on luminance changes at an early input stage. A computational model that integrates local signals was capable of extracting illusory edges from SBF displays and accurately predicted human performance across several experiments. Multi-voxel pattern analysis of neuroimaging data and source localization from EEG recordings were consistent with other findings that global shape representations emerge early in higher-level visual areas and feed back onto earlier ones. A convergence of behavioral, computational, and biological evidence indicates that SBF is a robust process that relies on several processing stages.

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23.336 **Combination of contour convexity and accretion/deletion in the perception of relative depth** Ö. Dağlar Tanrıkulu[1](odt7@eden.rutgers.edu), Vicky Froyen[1], Lynn Ma[1], Jacob Feldman[1], Manish Singh[1]; [1]Psychology Department, School of Arts and Sciences, Rutgers, The State University of New Jersey

Accretion/deletion is widely considered a reliable cue to depth ordering, with the accreting/deleting surface perceived as behind the adjoining surface. However, Froyen et al. (2013, JoV) showed that when accretion/deletion occurs on both sides of a contour, the resulting ambiguity in depth ordering can be resolved by geometric figure-ground cues such as convexity. Specifically, convex accreting/deleting regions were perceived as in front and as self-occluding due to rotation in 3D, despite the constant speed profile. Tanrikulu et al. (2013, VSS) further showed that the perception of 3D rotation can also occur when only one side of a border had accreting/deleting texture, which contradicts traditional interpretations of accretion/deletion. Here we examine how convexity and accretion/deletion combine. Our displays contain alternating light and dark regions with random dots moving horizontally at constant speed, but in opposite directions in alternating regions. We manipulated relative strength of convexity and relative texture density in the two sets of regions. Convexity was manipulated quantitatively, ranging from unbiased to strongly biased (i.e., with sharper negative minima of curvature on one side). Relative texture density was manipulated so that it either cooperated or conflicted with the convexity cue. Subjects reported which set of regions was seen as a single sheet translating in the background. Increasing the degree of convexity in a region made it more likely to be perceived as figural, whereas increasing the density of the accreting/deleting texture made it less so. However, convexity exerted a stronger influence on figural status, while the effect of texture density was only prominent when convexity was weak. Our results show that, even moderate levels of convexity can override standard depth from accretion-deletion. These findings cannot be explained by traditional accounts of depth-from-motion, and point to a deeper interaction between contour geometry and dynamic cues than has previously been appreciated.

23.337 **Visual adaptation to symmetry** Elena Gheorghiu[1](elena.gheorghiu@stir.ac.uk), Jason Bell[2], Frederick A.A. Kingdom[3]; [1]University of Stirling, Department of Psychology, Stirling, FK9 4LA, Scotland, United Kingdom, [2]School of Psychology, University of Western Australia, Perth, WA, 6009, Australia, [3]McGill Vision Research, Department of Ophthalmology, McGill University, Montreal, H3A 1A1, Quebec, Canada

Aim: Mirror symmetry is a ubiquitous feature in visual scenes, especially in biological objects, and is believed to be encoded by specialized visual mechanisms. Here we examine whether perceived mirror-symmetry is susceptible to adaptation like other basic visual features. Method: Stimuli consisted of random-dot patterns of low dot density that were mirror symmetric about the vertical axis. We manipulated the amount of mirror symmetry by adding variable amounts of random jitter to the dot elements from their baseline positions. The amount of positional jitter determined the degree of randomness. Observers adapted to a pair of patterns in which one was perfectly symmetric and the other random, and the positions of the dot elements were randomly changed every half second during adaptation. Observers varied the relative amount of positional jitter in two subsequently presented test patterns with a mean intermediate amount of symmetry, using a conventional staircase procedure, until a PSE (point-of-subjective-equality) in perceived symmetry was reached. The size of the after-effect was measured as the difference in positional jitter between the two test patterns at the PSE. Results: We found that the perceived symmetry of the test patterns was reduced following adaptation to a perfectly symmetric pattern. Adaptation appeared to only cause the test pattern to look less symmetric, suggesting that symmetry adaptation is unidirectional. Conclusion: Mirror-symmetry is an adaptable feature in human vision that produces a 'symmetry after-effect', or SAE. The effect cannot be due to increased positional uncertainty of the dots caused by adaptation, as both of the test patterns were subject to the same amount of any positional adaptation. The SAE is therefore likely caused by adaptation of mechanisms sensitive to mirror-symmetry.

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23.338 **Is 20/20 vision good enough? Visual acuity differences within the normal range alter performance on contour grouping tasks** Danielle Paterno[1](paternda@ubhc.rutgers.edu), Brian Keane[1], Sabine Kastner[2], Steven Silverstein[1]; [1]University Behavioral Healthcare, Rutgers University, [2]Princeton University

Contour integration (CI) is a visual process that combines appropriately aligned and oriented elements into coherent boundaries and shapes. Collinear facilitation (CF) occurs when a low-contrast oriented element ("Gabor") becomes more visible when flanked by collinear high-contrast elements. Both processes rely at least partly on long-range horizontal connections in early visual cortex, and thus both have been extensively studied to understand visual cortical functioning in aging, development, and clinical disorders. Here, we ask: Can acuity differences within the normal range alter CI or CF? Method. To consider this question, we compared subjects with 20/20 vision to those with better-than-20/20 vision (Sharp-Perceivers) on two tasks. In the CI task, subjects detected the location of an integrated shape embedded in varying amounts of noise; in the CF task, subjects detected a low-contrast element flanked by collinear or orthogonal high-contrast elements. In each case, displays were scaled in size to modulate the visibility and spatial frequency of elements (4-12 cycles/deg). Results. We found that Sharp-Perceivers could integrate contours under noisier conditions than the 20/20 group especially for the high spatial frequency displays ($p<.001$). Collinear facilitation did not depend on acuity, but the 20/20 group exhibited overall higher contrast thresholds for the high spatial frequency displays ($p<.05$). Conclusion. These results suggest that small visual acuity differences within the normal range—equivalent to a one line difference on a vision chart—alters element detection and integration. Furthermore, simply ensuring that subjects have normal or corrected-to-normal vision is not sufficient when comparing groups on contour grouping or related tasks involving Gabors; visual acuity confounds also need to be considered.

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23.339 **Contour integration and its independence from attention, awareness, and task-relevance** Michael Pitts[1](mpitts@reed.edu), Antigona Martinez[2], Steve Hillyard[2]; [1]Department of Psychology, Reed College, [2]Department of Neurosciences, School of Medicine, University of California San Diego

Contour integration refers to the mid-level visual process in which spatially-separate edge information is grouped together to form object boundaries. Whether contour integration occurs automatically at an early stage of processing in the absence of attention or awareness is currently debated. Previous event-related potential (ERP) experiments have investigated a purported index of contour integration: a negative amplitude deflection over the posterior scalp from ~150-300ms elicited by contour-present versus contour-absent stimuli. Here, we report a series of recent experiments in which this same contrast was made while spatial attention, task relevance, and conscious perception were systematically manipulated. In all experiments, contour-present and contour-absent stimuli were formed by altering the orientation of a subset of lines within larger arrays of randomly oriented line segments. ERPs elicited by the orientation changes were first compared according to whether a contour was present or absent and the resulting ERP differences were then assessed according to attention, awareness, and task-relevance. In one experiment, spatial attention and task relevance were manipulated in a 2x2 crossed design. In another experiment, an inattentional blindness paradigm was employed to render the contours perceptually invisible to roughly half of the participants. Overall, results across a number of experiments converged to indicate that only the early phase of the contour-specific ERP difference reflects contour integration per se, while subsequent phases reflect perceptual, attentional, and task-related processes. The latency of the contour integration component is strongly modulated by the subjects' task, while its amplitude varies according to physical characteristics of the stimuli. Importantly, these experiments demonstrate that while contour integration requires spatial attention it can be carried-out nonconsciously during inattentional blindness and does not require task-based attentional selection.

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23.340 **Contour perception across time and eye movements** William Harrison[1](willjharri@gmail.com), Peter Bex[1]; [1]Schepens Eye Research Institute, Department of Ophthalmology, Massachusetts Eye and Ear Infirmary, Harvard Medical School

Our visual environment is replete with partially occluded objects. Despite having discontiguous edges, partially occluded objects are nonetheless often easily identified. We used Kanisza figures to investigate how such perceptual completion of contour segments is affected by changes in contour information across time and shifts of gaze. Observers were required to identify the apparent shape of illusory contours constructed from four pacmen (58ms duration) positioned at the corners of an invisible square. We varied the angle of the pacmen to produce apparently "fat" or "thin" illusory shapes, and defined an observer's identification threshold as the standard deviation of a cumulative Gaussian fit to their responses. Critically, we presented masking discs of variable durations at positions corresponding to each of the pacmen, and these discs could appear either before or after the illusory contours. Observers' thresholds increased when masks were presented immediately after the illusory contours, as per backward masking. However, when the discs preceded the illusory contours, we saw a strong and robust reduction in thresholds for even the shortest mask duration (25ms). We then tested whether this facilitation of perceptual completion depends on retinotopic brain areas. Observers executed a saccade and identified an illusory shape presented immediately after the eye movement. In one condition, we presented the disc masks prior to the saccade at a screen location corresponding to where the pacmen would appear following the saccade. Because of the intervening eye movement, these discs were retinotopically mismatched from the pacmen. Nonetheless, thresholds were lower when discs preceded the illusory contours (and saccade) compared with a condition in which no discs were presented prior to the saccade. Our data are consistent with the notion that feedback from non-retinotopic brain areas plays an important role in perceptual completion, and that this feedback can facilitate visual perception across eye movements.

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23.341 **Conscious awareness is necessary for the integration of orthogonal but not collinear contours** Ya Li[1](liya826@gmail.com), Sheng Li[1,2,3]; [1]Department of Psychology, [2]Key Laboratory of Machine Perception (Ministry of Education), [3]PKU-IDG/McGovern Institute for Brain Research, Peking University, Beijing,China

The model of association field proposed that local elements are integrated into global contours if they satisfy the joint constraints of local alignment and spatial position along first-order curves (e.g., collinear contours). However, it is difficult to interpret the surprisingly good detection performance when the elements of the contour align perpendicular to its underlying path (i.e., orthogonal contours) with the model. This raised the debates on whether orthogonal contours share the same integration mechanism with collinear ones. We addressed this issue, in particular, by investigating the role of conscious awareness in the processing of collinear and orthogonal contours. In Experiment 1, we combined an attentional cuing paradigm with a modified version of inattentional blindness paradigm to examine the processing of collinear and orthogonal circular contours under conscious and unconscious conditions. We found that collinear contours induced a positive cueing effect at both unconscious ($p<0.01$) and conscious ($p<0.01$) conditions, while orthogonal contours summoned attention only under conscious condition ($p<0.05$). In Experiment 2, we tested whether collinear and orthogonal contours presented under continuous flash suppression have prioritized access to awareness relative to the Gabor field without a contour (random field, baseline condition). We found that the collinear contours broke from suppression more quickly than the random field ($p<0.001$). However, no such effect was observed for orthogonal contours ($p=0.55$). These results demonstrate that collinear contours can be processed without conscious awareness, supporting the idea that its integration implements through lateral interactions within the primary visual cortex. On the other hand, the integration of orthogonal contours requires conscious awareness with at least higher visual cortex involved. Taken together, different fates of collinear and orthogonal contours at unconscious level provide strong evidence that the integration of orthogonal contours is mediated by a different mechanism than collinear contours.

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23.342 **Spatially-global interpolation of closed curves** Taekyu Kwon[1](kwont@purdue.edu), Yunfeng Li[1], Michael Scheessele[2], Aaron Michaux[1], Zygmunt Pizlo[1]; [1]Department of Psychological Sciences, College of Health and Human Sciences, Purdue University, [2]Department of Computer and Information Sciences, Indiana University South Bend

Most previous methods focused on spatially local interpolation using rules such as proximity, co-linearity, co-circularity and relatability. We propose a spatially global model based on finding the shortest path in the log-polar representation of the image which is a good approximation to the topographical map of the retina in the area V1. The shortest path in a log-polar representation corresponds to a smooth, convex and closed curve in the retinal image. As such, our method implements two fundamental rules of Gestalt perceptual organization: closure and good continuation. The subject was shown a fragmented convex polygon (target) embedded in noise consisting of 300 line segments. A random polygon was generated as a convex hull of 10 randomly generated points. To minimize spatially local cues, the pairwise distances of the contour fragments in the target were randomized. Furthermore, the orientation of each contour fragment of the target was randomly perturbed by +/- 10 to 30 deg. Two subjects were asked to reconstruct the target by clicking the mouse on the line segments perceived as forming the target. The model was applied to the same stimuli. Both the subject and the model started the reconstruction at a line segment that was longer than other line segments. The subjects reconstructed the targets very reliably and the model produced closed contours that matched the ground truth quite well. We conclude that the human visual system uses both spatially global and spatially local interpolation mechanisms. We view the task of contour interpolation as a combinatorial correspondence problem, which is analogous to other computationally hard correspondence problems in vision such as stereo, motion, recognition and symmetry. The plausibility of the shortest path model is supported by existing results showing that humans produce near-optimal solutions to shortest path and traveling salesman problems in linear time.

23.343 **Sparseness and Surface Representation in the Generation of Curvature Selectivity** Yasuhiro Hatori[1,2](hatori@cvs.cs.tsukuba.ac.jp), Tatsuroh Mashita[1], Ko Sakai[1]; [1] Department of computer science, University of Tsukuba, [2]JSPS research fellow

Physiological studies have reported that V4 neurons represent curvature and its direction (Carlson et al., 2011). We investigated what controls the construction of the curvature selectivity, and what is necessary for the construction. We consider that sparseness is the key for understanding this issue. To investigate the sparseness in the construction, we applied sparse coding to the activities of model V2 neurons in response to natural images so as to obtain basis functions corresponding to the RFs of V4 neurons. With the sparseness ranged between 0.7-0.8, the curvature selectivity of each basis and their population activity emerged as similar to the physiology. This result indicates that sparseness is sufficient to control the construction of the curvature selectivity. In the model above, the RFs of model V2 neurons consisted of two Gabor filters. Depending on the combination of their phase, some models may represent a surface (e.g., vertically aligned cells with the same phase), but others may not. To investigate whether the surface representation is necessary for the construction of the curvature selectivity, we classified the models into the two categories, and analyzed the dependence of selectivity on the categories. Model neurons that included surface representation yielded curvature selectivity, and the others did not. This result indicates that surface representation is necessary for the construction of the curvature selectivity. Because appropriate sparseness was required for the construction of the selectivity, it is expected that the model V4 neurons with the selectivity should show the appropriate sparseness (0.7-0.8). To confirm this expectation, we compared the lifetime sparseness of the model cells and that of the basis functions. The distributions of lifetime sparseness were, in fact, very similar. These results indicate the crucial role of sparseness and surface representation in the representation of curvature and primitive shape in V4.

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Color and light: Lightness and brightness

Saturday, May 17, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

23.401 **When comparing illumination conditions observers rely more on cast shadows than on highlights and shading.** Susan F. te Pas[1](s.tepas@uu.nl), Sylvia C. Pont[2], Edwin S. Dalmaijer[1], Ignace T.C. Hooge[1]; [1]Experimental Psychology - Helmholtz Institute - Utrecht University, [2]Perceptual Intelligence Lab - Faculty of Industrial Design Engineering - Delft University of Technology

When comparing illumination conditions, human observers mostly extract the direction of the light source from low-level image cues. The question we ask here is how well they are able to distinguish other low-level aspects of illumination, like the diffuseness of the light and the number of light sources. We also investigate what kind of stimulus information is most important for this task. To address this question, we used pictures of a

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teapot, an orange and a tennis ball from the ALOI database (Geusebroek et al., IJCV 2005) to create 6 illumination conditions for each object. The objects are illuminated from a single direction and varying in diffuseness or from two directions that with varying separation. Observers are presented with all three objects on every trial, and have to indicate which one is illuminated differently from the other two. We measured performance and reaction times on every trial. We also recorded eye-movements to determine what part of the stimulus our participants were looking at to complete this task. Results show that participants performed above chance for most conditions, and there are systematic variations in performance for different conditions. These differences in performance were predicted well by a model that uses differences in image structure in same-object comparisons. This model suggests that participants mostly rely on the information in cast shadows to perform the task. Interestingly, participants primarily look at the shadows (roughly 60% of the fixations), in favor of shading (30%) and highlights (10%). When we look at the reaction times, we see that the pattern of results is similar as that of performance, suggesting that higher performance correlates with shorter reaction times. Moreover, when there is a larger difference in highlight structure the reaction times are shorter.

23.402 **The influence of scene layout and content on the perception of light direction in real scenes** Ling Xia[1](l.xia-1@tudelft.nl), Sylvia Pont[1], Ingrid Heynderickx[2]; [1]Department of Industrial Design, π-lab (Perceptual Intelligence lab), Delft University of Technology, [2]Department of Human Technology Interaction, Eindhoven University of Technology

Light is a kind of medium that makes objects visible without being visible itself in empty space. The combination of spatial and spectral characteristics of the light source, material reflectance and shape of an object determine its appearance, and as such the appearance of an object is the main cue for perception of its lighting. In the current study we tested whether types of shapes and scene layout influence lighting perception. In real scenes composed of several objects we tested observers' perception of lighting direction with a real light probe – using a novel experimental setup to optically mix the probe object into a real scene by a semi-transparent mirror. Participants (N=15) had to adjust the illumination direction on the probe such that it fitted the scene. We tested nine lighting directions for four different scenes, existing of five objects: a cylinder, star shape, and cross shape plus combinations of bowling pin(s) and pentagon shape(s). When using one bowling pin and one pentagon shape, the result showed that the light direction estimation was systematically contracted near the pentagon body, but not near the bowling pin. When horizontally mirroring this scene, also the light direction estimation was mirrored. Replacing the bowling pin with another pentagon body resulted in systematic contractions of the light direction slants near both pentagon bodies. Replacing the pentagon bodies with two bowling pins finally resulted in close to veridical light direction settings. The globally convex smoothly curved bowling pins, in comparison with the facetted pentagon shapes, improved observers' setting of light direction. Mirror arrangements of objects in the scene improved the estimation of the tilt direction. These very systematic effects suggest that human perception of the global "light flow" in a scene might be systematically deformed depending on scene layout and content.

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23.403 **Predictive Coding of Shape Affects the Perceived Luminance of the Surrounding Region** Biao Han[1,2](biao.han@cerco.ups-tlse.fr), Rufin VanRullen[1,2]; [1]Centre National de la Recherche Scientifique, Unité Mixte de Recherche 5549, Faculté de Médecine de Purpan, 31052, Toulouse Cedex, France, [2]Université de Toulouse, Centre de Recherche Cerveau et Cognition, Université Paul Sabatier, 31062, Toulouse, France

Predictive coding theory suggests that target-related responses in lower brain areas are "explained away" (i.e., reduced) by feedback from higher areas. In practice, predictive coding models rely on feedback signals that must be precisely tuned to each potential target; a computationally simpler and biologically more plausible strategy could be to use spatially distributed feedback affecting both the target and its surrounding region. We tested this hypothesis by measuring luminance perception around potential targets. As in (Murray et al., 2002), we used two stimulus groups: 3D shapes and random lines created by breaking the 3D shapes at their intersections and shuffling the resulting lines. These stimuli differentially activate higher areas, resulting in different amounts of predictive feedback. In each trial, one 3D shape and one random-lines stimulus were shown simultaneously on the left and right of fixation (randomly assigned); each stimulus was presented on a gray disk, and subjects were asked to compare the luminance of these disks (report the side of the brightest disk). One disk had a fixed luminance value while the other varied around that level. We created psychometric functions for the choice probability of each disk as a function of its luminance, and compared these functions for the disk behind the 3D shape versus the one behind the random lines. Results (N=11) indicate that predictive feedback affects background luminance perception. The 3D-shapes disks were perceived brighter and the random-lines disks darker by 4.37% on average. To control for any potential attention bias, we repeated this experiment while observers were engaged in a demanding rapid serial visual presentation task. The perceptual luminance gain was still present, even though attention was engaged away from the 3D shapes and random lines. Thus, predictive feedback signals are not restricted to the predicted input, but also affect the spatial region surrounding it.

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23.404 **Influence of spatial structure with no explicit luminance information on lightness perception** Kei Kanari[1](kei.kanari@ip.titech.ac.jp), Hirohiko Kaneko[1]; [1]Department of Information Processing, Tokyo Institute of Technology

Some studies have shown that spatial structure of the scene affects lightness perception. However, most of them focus on the context of the surrounding luminance presented explicitly in the scene. This study investigated whether lightness perception is influenced by the spatial structure with no explicit information of luminance. In addition, we measured the illumination and the volume of space in actual scenes to examine whether the size of space in our environment was related to the illumination in the space. We used the stimulus consisted of the random-dots with 3D structure defined by binocular disparity. Since the density of dots was kept uniform over the stimulus, the influence of luminance and texture should be eliminated. Observers matched the lightness of a test patch presented in the stimulus space to that of a comparison patch presented in isolation by adjusting the comparison patch luminance. In experiment 1, we changed the angle of the ceiling of the stimulus space above the test patch to intend manipulating magnitude of illumination based on the light-from-above assumption. In experiment 2, we changed the width of the stimulus space to test whether observed positive correlation between the illumination and the volume of space in actual scenes was used for lightness perception. Results showed that matched luminance significantly increased when the space was opened and the width of space was increased, in other words, when the test patch was interpreted to receive weak illumination. These results suggest that the visual system could refer implicit information of the illumination of the scene from spatial structure for lightness perception.

23.405 **Luminance gradient configuration determines perceived lightness in a simple geometric illusion** Maria Pereverzeva[1](mariape@u.washington.edu), Scott O. Murray[1]; [1]Dept. of Psychology, University of Washington, Seattle, WA

Accurate perception of surface reflectance poses a significant computational problem for the visual system. The amount of light reflected by a surface is affected by many factors including the surface's reflectance properties and illumination conditions. The latter are not limited by the strength of illuminant but also include the relative placement of light illuminating the surface, the orientation of the surface and its 3d shape, all of which result in a pattern of luminance gradients across the surface. In this study we explore how the presence of luminance gradients in parts of the image contributes to lightness perception. We introduce a novel, simple lightness illusion. It consists of six separate checks, organized in rows of two. Each check has a positive luminance gradient across it. The top and the bottom rows are the same: with the darker check on the left, and the lighter check on the right. Two checks in the middle row are identical; however, the right check appears darker than the left. 3-7 subjects participated in 10 conditions of the experiment, with various stimulus configurations. The illusory "darker" check was perceived on average 12% IL (IL=100%*(L-Lmin)/(Lmax-Lmin), L=stimulus luminance, Lmin=monitor black level, Lmax=display maximal luminance) darker than the veridical luminance match. Reversing the gradient orientations of the middle row checks eliminated the illusion. Surprisingly, the illusion was still present, (even though decreased, at about 5%IL,) when the top and the bottom row were substituted by identical, spatially uniform gray checks. As there are no shared borders between the checks, simultaneous contrast cannot explain the effect. However, there are multiple possible explanations including spatial filtering (Blakeslee & McCourt, 2004) or by some higher-order mechanism such as perceptual grouping or amodal completion. We explore these possibilities by manipulating the luminance configurations and the gradient slopes of the checks.

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23.406 **Size and color do matter in the prediction of brightness**

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Introduction In addition to luminance, other (secondary) factors such as stimulus size (larger is brighter) and saturation (higher is brighter: Helmholtz-Kohlrausch effect) have an impact on perceived brightness. In this study, the former was systematically investigated for self-luminous stimuli. In particular, the accuracy of the CIE 2° and 10° luminance to predict perceived brightness was examined. In addition, the magnitude of the stimulus size effect was compared to that of the Helmholtz-Kohlrausch effect. Methods A gender balanced group of ten observers (average age: 23 years) with normal color vision were asked to match the brightness of a 2° or 10° stimulus to respectively a 10° or 2° achromatic reference stimulus presented simultaneously. The initial luminance, the test and reference stimulus sizes, as well as their respective locations (either above or below) were counter balanced to reduce bias. Data on thirty stimuli, covering a wide chromaticity gamut and with a luminance of approximately 60 cd/m², was collected. Stimuli were generated by size-adjustable circular openings in a box in which two RGB LED modules were mounted. Results After matching, the luminance (either 2° or 10°, depending on stimulus size) of each stimulus was measured and averaged over all observers, giving the following results for counter balanced stimulus sizes: - For equal chromaticity stimuli, the 2° luminance is on match consistently higher than the 10° luminance. - Saturated stimuli matched to an achromatic stimulus show a consistently lower luminance, illustrating the H-K effect. Conclusion When perceiving brightness the saturation or Helmholtz-Kohlrausch effect was found to be stronger than the size effect, which was insufficiently corrected by a switch from the CIE 2° to the 10° luminance. The magnitudes of the observed effects suggest they are non-negligible and should be accounted for in any Colour Appearance Model.

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23.407 **Temporal dynamics of brightness induction from motion in context**

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Recently we show that motion signal from neighboring objects alters brightness of both the moving and the stationary objects, and consequently the stationary objects appear different from the moving ones although both have identical physical luminance (Hong & Kang, 2013). In the current study, we investigated the temporal dynamics of this novel brightness induction. When two stationary dots were presented initially then one of them was set in motion, brightness of both stationary and moving dots changed almost instantaneously. Concerning that the abrupt onset of the stimulus motion might be responsible for this instantaneous change, we abruptly introduced the stationary dot also. When a stationary dot was introduced while a dot was moving, the appearance of the newly appeared stationary dot changed slowly over two seconds. Further, when an additional stationary dot was introduced in the display where one stationary and one moving dots were already present, the additional dot underwent slow change in brightness, similar to the previous condition. Lastly, when the moving dot stopped its motion, its brightness as well as the brightness of the stationary dot changed slowly and then they were indistinguishable in about 2 second. We discussed underlying mechanisms mediating this slow changes in brightness associated with stimulus motion.

23.408 **Predicting lightness rankings from image statistics of matte and glossy surfaces**

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Humans are able to estimate the reflective properties of the surface (albedo) of an object despite the large variability in the reflected light due to shading. We investigated which statistics of the luminance distribution of matte and glossy three-dimensional virtual objects are used to estimate albedo. Eight naive observers were asked to sort twelve objects in an achromatic virtual scene in terms of their albedo. The objects were positioned uniformly spaced on a horizontal plane, the scene was illuminated by a light probe captured in a natural scene. We chose twelve different reflectances which allowed observers to rank the objects better than chance but not perfectly. The scenes were rendered using radiance, a physically based rendering software. The twelve reflectance values were assigned randomly to the objects in the scenes. The twelve object placed in each scene were randomly chosen from a pool of twenty four tridimensional models, ranging from simple geometrical shapes to complex real object models. Observers were significantly better in ranking matte objects (82% correct) than glossy ones (72% correct). The physical ranking of matte objects was best predicted by the maximum of the luminance distribution whereas the best predictor for the glossy objects was the mean of the distribution. Similarly, the observers judgments for matte objects were best predicted based on the mean, maximum and quartiles of the distribution whereas for glossy objects the maximum was a poor predictor of the observers' judgments. In summary our data suggest that histogram statistics of the luminance distributions of complex objects can support the recovery of their surfaces albedo, despite the fact that this distributions results from the complex interplay of geometry and the structure of the illuminant.

23.409 **Modeling asymmetric responses to increments and decrements in brightness, disk-annulus, and staircase-Gelb paradigms**

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Both ON- and OFF- neuronal responses, and perceptual responses to increments and decrements, exhibit strong asymmetries, consistent with the idea that darkness induction is inherently stronger than brightness induction. These asymmetries are also observed in lightness, e.g. staircase-Gelb displays, when the Gelb papers are viewed against dark versus light backgrounds (Cataliotti & Gilchrist, 1995). Here, I attempt to found a computational lightness theory that properly incorporates light-dark asymmetries, and includes both low- and mid-level spatial context effects. I begin at the lowest level: with Stevens' power law, which models the brightness (or darkness) of an isolated increment (decrement) viewed against a homogeneous background. The brightness exponent is 1/3; the darkness exponent is 1. To model matching data, it is convenient to express the power law in logarithmic form. The exponent then becomes a weight multiplying the step in log luminance from background to target. We know from past work that the lightness of a disk surrounded by one or more concentric annuli can be modeled as a weighted sum of edge-based induction effects, where edge weights decline with distance from the target. Combining this result with the assumption that the weights associated with edges whose light sides point towards the target are always 1/3 and the weights associated with edges whose dark sides point towards the target are 1 (after controlling for distance) yields an edge integration model that explains quantitative data on either brightness or lightness, depending on context. To quantitatively model the staircase-Gelb data, these low-level factors must be supplemented with an additional, image segmentation, principle: only edges between the Gelb papers and their common background participate in the edge integration process (Rudd, J. Vision, in press). The theory differs from other lightness theories in that the light-dark asymmetry results from low-level factors, rather than highest luminance anchoring.

23.410 **Why do failures of lightness constancy take the form of gamut compression?**

Alan Gilchrist[1](alan@psychology.rutgers.edu), Stephen Ivory[1]; [1]Psychology Dept, Rutgers University

The pattern of failures of constancy provides a kind of signature of the visual software serving constancy. In scenes containing two or more regions of illumination (i.e., almost always) the range of lightness values is compressed relative to the actual range. To exploit this important clue, we measured gamut compression for a row of 5 target squares, of various gray shades, standing in a spotlight (30 X ambient) suspended inside a vision tunnel lined with checkerboard walls. By varying the luminance range of both the 5 squares and the checkerboard walls we produced 6 conditions (n=15, between subjects) used to test 5 stimulus metrics potentially underlying the compression. The amount of compression was predicted by the ratio of highest target luminance to highest checkerboard luminance (equivalent to perceived illumination difference), but not by overall luminance range nor by the formula in anchoring theory nor by two other metrics. Two additional experiments were run to test the hypothesis that the compression results from a lack of information about the spotlight/ambient illumination difference. To exclude any assumption that the ambient illumination applies to the 5 squares, they were moved into a second room and seen through an aperture, with luminances and sizes held constant. Compression was identical, suggesting that border ownership at the occlusion boundary enclosing the squares is not critical. To reveal exactly the spotlight/ambient illumination difference we placed the row within a rectangular beam of light projected onto the far wall of the original room. Rather than reducing the compression, this produced significantly more compression, suggesting that an occlusion boundary segregates frameworks of illumination better than a cast illumination boundary. Overall our results appear to require a major overhaul of anchoring theory, perhaps with both an anchor and a coefficient of scaling established within each framework.

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23.411 **Anchoring Theory, Staircase Gelb Effect, and Gamut Compression.** Stephen Ivory[1](steveivory@psychology.rutgers.edu), Alan Gilchrist[1]; [1]Rutgers University at Newark

When a row of 5 squares ranging from white to black are suspended in midair and illuminated by a spotlight thirty times brighter than overall room illumination the perceived range of gray shades is compressed relative to the actual range. That is, plotting lightness range against actual range produces a slope less than 1. According to anchoring theory, the lightness of a surface is a weighted average of its lightness within its local framework (spotlight) and within the global framework (whole field). The compression stems from the provision that, when the spotlight is 30X, all 5 squares are assigned the same value of white, because each has a luminance equal to (or exceeding) that of a white in the global framework. However, no further compression is predicted even if the spotlight becomes brighter, because their global values are maxed out. Purpose: (1) test the prediction that maximum compression occurs with a 30X spotlight; (2) test whether compression depends on absolute or relative illumination levels. Fifteen subjects matched 5 squares for lightness in each of 3 conditions. In Condition 1, the spotlight was 30X room illumination. The slope of the plot was .42 (white to middle gray). In Condition 2 spotlight intensity was increased by 4X, producing a significantly lower slope of .30 (white to light gray). In Condition 3, spotlight intensity was equal to that of Condition 1 but overall room illumination was reduced by 4X, producing a slope of .29. These results show that the compression depends on relative illumination, not absolute. But they also contradict the theory's prediction of maximum compression and appear to require a major modification of the theory.

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23.412 **Goal-seeking approaches to characterize non-CRT as well as CRT displays for vision experiments** Hiroshi Ban[1], Hiroki Yamamoto[2]; [1]National Institute of Information and Communications Technology, Center for Information and Neural Networks, Osaka, Japan, [2]Graduate School of Human and Environmental Studies, Kyoto University, Kyoto, Japan

Display characterization is an important part of the experimental procedures in vision science since almost all current experiments are controlled by computers and the visual stimuli are presented on computer displays. A two-step procedure (gamma-correction and the following linear color transformation) has been widely used to calibrate display luminance and chromaticity profiles to ensure that visual stimuli are presented accurately. However, the standard procedure is not always valid to characterize recent new types of displays such as LCD (Liquid Crystal Display), DLP (Digital Light Processing), and OLED (Organic Electro-Luminescence Display) because the method was developed based on the internal model of CRTs (Cathode Ray Tube). Furthermore, these new types of displays have come into the mainstream of display products and it becomes increasingly difficult to obtain CRTs. Therefore, vision researchers are required to develop new display characterization approaches that are appropriate to any display type. Here we propose novel display characterization methods that are applicable to non-CRT as well as CRT displays. Our aim is especially focused on developing fairly quick and efficient methods for finding display inputs that produce specific pre-specified luminance and chromaticity output values. Our new methods use a data-driven gamma-correction procedure combined with recursive-linear and non-linear goal-seeking algorithms. The methods are relatively model-free, only assuming a piece wise linearity of the system in the initial estimation step. The whole procedures are integrated into GUI-based display characterization software, Mcalibrator2, written in MATLAB (Ban and Yamamoto, J. Vis. (2013). The software is now publicly available and can be downloaded from our website). The present study further tested the efficiencies and accuracies of our new methods to produce chromatic visual stimuli on non-CRT displays. The results showed that our methods significantly outperformed the standard procedure and were applicable to a wide range of display devices.

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23.413 **The Perceived Quality of Undistorted Natural Images** David Kane[1](d.kane.berkeley@gmail.com), Marcelo Bertalmio[1]; [1] Information and Communication Technologies, Universitat Pompeu Fabra

We investigate the perceived quality of natural images. To do so, we linearly scale the luminance range of high dynamic range images to generate a set of tone-mapped images that cover the full range of mean-luminance and contrast values that a CRT monitor can display. Image patches are displayed on a uniform black, grey or white background and subjects are asked to evaluate the quality of each image on a 0-9 scale. We find that image quality scores can be predicted using a three-stage model: First, luminance is converted to lightness using an expansive power-law that varies with the background luminance (γblack=0.3, γgray=0.35, γwhite=0.45). Second, the standard deviation of the gamma-adjusted, lightness image is computed. Third, the standard deviation is passed through an expansive power-law (γ=0.3) to estimate the perceived contrast of an image. This metric can accurately predict the average image quality scores over the full range of onscreen luminance and contrast values investigated (r=0.94, p<0.0001). A second investigation reveals that the proposed contrast metric is linearly related to image quality scores for all test images with a mean Pearson's correlation of 0.87 (N=128), however the slope of the function varies substantially between images and we are unable to model this effect. The proposed contrast metric is able to predict the perceived quality of tone-mapped images in the database of Cadik et al. (2008) despite the existence of a wide variety of image artefacts (ringing, colour distortions, ect) in the image set (r=0.85, p<0.0001). Finally, we note that the proposed super-threshold contrast metric performs histogram equalisation on the luminance distribution and removes skew from the contrast distribution of natural scenes, suggesting an optimal coding strategy.

23.414 **A perceptually uniform tone curve for OLED and other high dynamic range displays** Andy Vargas[1](advargas@berkeley.edu), Paul Johnson[1], Joohwan Kim[2], David Hoffman[3]; [1]UC Berkeley – UCSF Graduate Program in Bioengineering, [2]UC Berkeley Vision Science Program, [3]Samsung Display Americas Lab

The next generation of displays uses organic light-emitting diodes (OLEDs). Such displays make it possible to display darker blacks than liquid-crystal displays (LCDs), providing a significantly larger dynamic range. We performed photometric and psychophysical measurements with an OLED display. We found that the widely used tone curve with a gamma value of 2.2 does not produce equally discriminable luminance steps in these displays. In a 2-alternative, forced-choice psychophysical task, subjects discriminated the luminances of adjacent square patches. We used spatial dithering to create small apparent changes in luminance. We measured the minimum perceivable change in luminance for a range of luminances. From these discrimination thresholds, we estimated the tone curve and necessary number of discrete steps that would fully cover the dynamic range in threshold-sized steps. Compared to the conventional tone curve, our experimental tone curve has smaller luminance differences in the low range and greater luminance differences in the high range, in accordance with Weber's law. This suggests that the conventional 2.2-gamma tone curve suffers from quantization issues at low luminance values and loss of detail at high luminance values. The conventional tone mapping is reasonably effective when the display has a low dynamic range of 100:1, but as dynamic range is increased, the conventional mapping increasingly diverges from a perceptually uniform mapping, so 8-bit gray levels are increasingly inadequate. Our research suggests that image quality can be significantly improved by using higher dynamic range displays with tone-mapping functions and bit depth that are appropriate for that range.

23.415 **A model of color constancy and efficient coding can predict lightness induction** Marcelo Bertalmío[1](marcelo.bertalmio@upf.edu); [1]Universitat Pompeu Fabra

A recent variational implementation of Land's Retinex theory of color vision can improve the appearance of images without introducing artifacts (Bertalmío et al. 2009). Through anti-symmetrization of the resulting partial differential equation, this methodology emulates color constancy on both under and over exposed images. Remarkably, this formulation of Retinex is formally equivalent to local histogram equalization and has the same form as the Wilson-Cowan equations that model the response of populations of cortical neurons. The model cannot predict the phenomena of color assimilation because it can only increase the contrast of an image. However an addition to the model, designed to allow it to reach a steady state in a constant time regardless of stimulus structure, can predict assimilation. This approach weights the magnitude of each convergence step by computing the ratio of image variance and histogram uniformity. This model can predict the perception of achromatic induction from the data of Rudd (2010) investigating the perceived lightness of a disk-and-ring stimulus. In particular the model predicts when contrast switches to assimilation, and it can also predict how the slope and curvature of such functions vary with ring width and polarity.

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23.416 **Chromatic and Luminance Asymmetries in the Watercolor Effect** Andrew Coia[1](andrewcoia3@gmail.com), Kamila Flake[1], Scott Arn[1], Gwen Amsrala[1], Michael Crognale[1]; [1]University of Nevada Reno

The watercolor illusion is a perceived spread of color when a thin colored line is adjacent to an outer luminance line or edge. Our prior work found an asymmetric color dependence for the watercolor illusion, with contrast matched +S stimuli producing larger effects than –S stimuli. In experiment 1 we show that the outer luminance line also shows an asymmetry that is also asymmetric with larger induction with increments than with decrements. This asymmetry is also color dependent, larger along the +S direction. To investigate the mechanism for this effect we measured the perceived contrast of increments vs. decrements as a function of color direction. In general, the luminance increment required to match a decrement was less than a decrement required to match an increment, but only for stimuli with +S input. These results are consistent with those of experiment 1 and suggest that the asymmetry may be driven by the apparent contrast of the inducing patterns. It is unclear why the apparent contrast of the luminance increments and decrements when paired with colored lines should have color dependence.

23.417 **Figure-ground inversion by neon-color spreading** Yong-Guk Kim[1](ykim@sejong.ac.kr); [1]Dept. of Computer Engineering, Sejong University

In the conventional neon-color pattern such as Ehrenstein one, color spreading from the inner grey cross, locating between four black branches and the white background, allows us to perceive a circular transparent veil overlapped on a black cross. The color spreading phenomenon persists as long as the luminance of the inner cross is intermediate between those of the background and the branches, called it Metelli's law (Nakayama et al, 1990). And it is known that the luminance relationship (LR) around each T-junction within the neon pattern uniquely determines whether one could see color spreading or not. To test its generality of such luminance rule, a new pattern is designed: a white cross occludes a grey disk with the black background. Notice that although the LR around each T-junction in the new case is identical to the above case, the neon-color phenomenon is absent. However, the grey disk is seen in front of the white cross as the luminance of the grey areas is increased and almost reached to that of the white cross, accompanying with the neon-color effect spreading into the white cross from four grey areas. Thus, the occluded disk becomes a transparent disk hanging over the cross, i.e. the figure-ground inversion. In addition it is found that this effect can be observed within other T-junction figures that contain occluded grey areas, and its strength depends on the width of the occluder, following Petter's rule. Results suggest that neon-color spreading is perceived within new patterns having occluded greys as well as the conventional neon-color displays.

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23.418 **Indirect and direct manipulation of saturation modulates the light levels at which brown stimuli can be perceived** Tanner DeLawyer[1](delaw005@uw.edu), Steven Buck[1]; [1]University of Washington

Stimuli that appear yellow when brighter than their surroundings will appear brown when they are darker than their surroundings. Past research (Bartleson 1976) has suggested that desaturated stimuli produce more effective browns than those that are fully saturated. The perceived saturation of brown stimuli can be manipulated both indirectly (by changing the size and location of the stimulus) and directly (by changing the amount of blue present in a brown stimulus). We sought to test the effect of stimulus saturation on the perception of brown stimuli quantitatively by varying, both indirectly and directly, the saturation of a test stimulus. Observers freely adjusted the luminance of a constant-chromaticity, 2°-7°-diameter saturated (CIE 10° x=.44, y=.46) or desaturated (CIE 10° x=.36, y=.36) disk, presented with a bright white surround (141 cd/m2, CIE 10° x,y .29,.29) on a CRT monitor. The disk stimulus was presented either at the fovea or at 7° eccentricity of a foveal fixation point. The observers adjusted the luminance until they reached the highest light level at which the stimulus appeared exclusively brown. Thus, the stimulus appeared brown at luminances lower than the boundary and appeared yellow at luminances higher than the boundary. For both foveal and 7° eccentricity conditions, smaller disks allowed the subject to perceive brown at significantly higher light levels than larger disks. Additionally, stimuli presented extra-foveally and desaturated stimuli facilitated perception of brown at significantly higher light levels than foveal stimuli and saturated stimuli. Smaller and eccentric test stimuli are more effective at producing brown than larger or foveal stimuli as are desaturated stimuli. Past research has shown both small stimuli and extra-foveal stimuli are perceived as less saturated than large or foveal stimuli (McKeefry et al. 2007) suggesting all these effects can all be attributed to perceived saturation. Potential nerual mechanisms are under investigation.

Eye movements: Cognition

Saturday, May 17, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

23.419 **A Boundedly Optimal State Estimation & Control Model of Detecting Targets Among Salient Distractors** Christopher Myers[1](christopher.myers.29@us.af.mil), Nicole Jardine[2], Joseph Houpt[3], Andrew Howes[4], Richard Lewis[5]; [1]Air Force Research Laboratory, [2]University of Iowa, [3]Wright-State University, [4]University of Birmingham, [5]University of Michigan

"Salient" distractors can capture attention and affect saccades, accuracy, and response speed in target-detection tasks. Salience may be based on some combination of the physical conspicuity of information in a scene and deliberate control. Recently, a model of boundedly optimal state estimation and control demonstrated saccadic bias toward the minority distractor in a distractor-ratio task without appealing to physical conspicuity/salience (Myers, Lewis, & Howes, 2013), but salience could also explain the result (Theeuwes, 1993). The present experiment was designed to determine whether saccade and manual response behavior in a singleton-distractor task could be accounted for with the same boundedly optimal model without a salience calculation. Perceptual errors in the model are caused by spatial uncertainty of features at greater eccentricities, leading to a greater likelihood of feature migration. The model optimally estimates the likelihood of each of the displays given the noisy perceptual samples (which may be corrupted by feature migration) to produce manual and oculomotor responses for each trial. Participants detected the presence of a target (red X) in a speeded search task. All displays contained two pairs at 8°, 12°, 16°, or 20° visual angle on each side of the center. Displays contained target-colored items (red O) and a conspicuous color singleton that may share the target shape (green X or O). Participants' manual responses were slower and more accurate for target-absent trials, and saccades were initiated toward the color singleton on 25%—40% of trials, depending on target presence and whether the color singleton was the target shape. The optimal model completed the same task by estimating the content of the display. The model produced RT distributions and accuracy performance similar to humans, suggesting that an explicit conspicuity calculation may not be necessary to explain behavior in simple search tasks with a "salient" singleton.

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23.420 **Chess players' eye movements reveal rapid recognition of complex visual patterns** Heather Sheridan[1](H.Sheridan@soton.ac.uk), Eyal Reingold[2]; [1]University of Southampton, UK, [2]University of Toronto, Canada

A key component of chess expertise is the ability to efficiently encode domain-related perceptual configurations. To explore this perceptual component of chess expertise, we monitored the eye movements of expert and novice chess players while they engaged in a chess-related "visual search" task that was designed to test anecdotal reports that a key differentiator of chess skill is the ability to visualize the complex moves of the knight piece. Specifically, the chess players viewed an array of four minimized chessboards, and they were asked to rapidly locate the target board that allowed a knight piece to reach a target square in three moves. On each trial, there was only one target board, and the remaining "lure" boards blocked the knight's path on either the first move or on the second move. The chess experts displayed longer first-fixation durations on the target board than on the lure boards, which suggests that chess experts can rapidly differentiate complex chess-related visual patterns. Interestingly, this first-fixation effect was driven by a subset of trials in which the experts displayed a single dwell on the target, and it was absent on trials in which the experts showed multiple dwells on the target board. Unlike the experts, the novices' first-fixation durations did not differentiate between targets and lures, and the novices displayed higher numbers of dwells and fixations than the experts. As hypothesized, the task differentiated chess skill, such that reaction times were more than four times faster

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for the experts relative to novices, and the reaction times of the experts were strongly correlated with their official chess ratings. These results indicate that visual expertise in chess involves the ability to rapidly recognize complex perceptual patterns, and to process chess stimuli in terms of larger patterns (i.e., holistic processing) rather than individual features.

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23.421 **Dissociating Semantic and Pragmatic Information in Eye Movement Data for Image Processing Tasks**

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Eye-movements recorded during image processing tasks are influenced by the image content (semantic-information) and the image processing task (pragmatic-information). To analyze the image processing task it is necessary to separate these two. We empirically test a method to transform an image into variants that contain less semantic-information while preserving task relevant features, such as color impression, spatial color correlation and luminance. Analysis of eye-movements for a global contrast adjustment task demonstrates the applicability of this method. Images were taken from two semantic categories, namely landscape and macro images. These were further divided into two subcategories each, namely landscape images with or without water and macro images containing human or nonhuman focal objects. This allowed us to assess at which semantic level (main categories represent a coarse semantic level, subcategories a fine semantic level) this semantic-information reduction method can still be applied. The images from these categories were transformed, using this method, into three variants containing different amounts of semantic-information. Subjects performed global contrast adjustment task on these images, blocked such that each subject saw all images but only in one of the three semantic-information variants. Subjects chose a similar global contrast for images independent of the variant they saw, but fixation distribution and frequency were significantly different between the variants. Eye-movement patterns show that despite high similarity between subcategory images, our semantic-information reduction technique preserved the features that elicit subcategory specific and task relevant eye-movements. Our interpretation is that this method does not remove task relevant pragmatic-information even at fine semantic level, shown by similar performances in the global contrast adjustment task for all image variants. The benefit of our method is that eye-movements are not confounded by influences of semantic-information present in the original images.

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23.422 **Do task demands influence the perception of symmetry?**

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Extensive research was and is still conducted regarding symmetry (e.g. Eisenmann, 1967: preference for symmetry). Locher and Nodine (1973) investigated the influences of symmetry or asymmetry on eye movements. In a complexity rating task, they showed that fixation distributions to symmetrical figures were clustered in one-half, whereas there was no bias for asymmetrical figures. Fixation time and numbers did not differ. We hypothesized that eye movement differences to symmetrical or asymmetrical figures depend on the task participants have to fulfil. Twenty participants had to visually inspect same 24 stimuli as in Locher and Nodine (1973) and rate them according to their complexity (Experiment 1) and liking (Experiment 2). In Experiment 3, participants had to memorize and draw each figure. Time until participants rated/started drawing the figures (RTs) and eye movements were recorded. In Experiment 1 participants rated asymmetrical as more complex than symmetrical figures; RTs and fixation numbers did not differ. Ratings in Experiment 2 did not differ, but RTs and fixation numbers for asymmetrical were significantly higher than for symmetrical figures. In Experiment 3 RTs and fixation numbers for asymmetrical were significantly higher (almost doubled) than for symmetrical figures. There was no general preference for symmetrical figures. We could replicate findings by Locher and Nodine (1973), namely that time and number of fixations did not differ in a complexity task, however, time and number of fixations did differ enormously in the liking and drawing task (similar to results by Milisavljevic et al., 2011). Preliminary scan path analysis revealed in none of the tasks a general bias to one-half in symmetrical figures, but there were significantly more trials with biases towards one-half in Experiment 2 compared to the other tasks. Our results showed that different task demands influence eye movement patterns during the perception of symmetrical figures.

23.423 **The influence of spatio-temporal structure on sequential eye and arm movements to remembered visual targets**

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Introduction: People are better at performing sequential movements to remembered targets that possess spatial structure (Fagot and De Lillo, 2011). This structure can be acquired at once (E.g., if shown 4 dots that form a square simultaneously) or over time (if the 4 dots are shown one at a time). This study investigates how the temporal presentation of spatial structure affects the ability to perform sequential saccades, reaches, and coordinated saccades & reaches. Methods: 8 head-fixed subjects in a dark room were positioned in front of a 5X5 LED display that encompassed 20˚ of visual space horizontally and vertically. While maintaining fixation on the central LED, 3-6 peripheral LEDs were illuminated sequentially in one of three ways: 1) The LEDs formed a connected structure and were presented temporally in a "connect the dots" temporal order (spatio-temporal structure congruent), 2) The LEDs had the same spatial structure, but were presented temporally randomly (spatio-temporal structure incongruent), or 3) LED locations were random (unstructured). LEDs then extinguished and subjects performed sequential movements to the remembered locations of the targets in the order they were presented. Results: To date, the saccade data has been collected with the following preliminary analysis. For the spatio-temporal structure incongruent and unstructured conditions, there were more saccades to incorrect target locations and trials with at least one saccade error when only 3 saccades had to be performed versus 6. This was not seen in the spatio-temporal structure congruent condition. In the 6 saccade condition, subjects were less likely to make a saccade error on the 4th or 5th saccades in the spatio-temporal structure congruent condition as compared to the other 2 conditions. Conclusion: Presenting targets that are spatio-temporally congruent reduces saccade errors. We are currently collecting reaching data on this paradigm to investigate if these results are effector specific.

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23.424 **The influence of prediction violations on eye movement patterns in a LTM-driven multi-step sensorimotor task**

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Prior studies revealed that prediction-violating stimuli are more often and longer fixated than prediction-confirming stimuli. This effect has been found in visual-search, change-detection, and memory-recall tasks. It is interpreted as prioritized processing of prediction-violating (surprising) stimuli. For preparing an action, action-relevant features have to be predicted and tested. Irrelevant features are usually completely ignored. Until now, it has not been tested how prediction-violating features that are either action-relevant or action-irrelevant influence gaze patterns in a sensorimotor task. We manipulated predictability and action-relevance in a computerized version of the number-connection task. Participants clicked on numbered shapes in ascending order. 60 trials were performed with the same spatial arrangement of 8 numbered shapes. In the consecutive 20 trials, the locations of two action-irrelevant features (shapes surrounding number 3 and 6) were exchanged in one group while the locations of two action-relevant features (numbers 3 and 6) were exchanged in another group. In a third group both changes appeared and no changes were executed in a control group. In 20 final trials, participants had to work again on the original configuration. Results revealed worse clicking performance, more fixations, and shorter fixation durations after an action-relevant change (switched numbers) only. The effects lasted for several trials. Micro-analyses revealed that the effects were completely due to an enhanced number of searching fixations but not guiding fixations, especially while searching for number three. We conclude that predictions for multi-step actions are formed only for action-relevant features and tested in each run. In addition, elongated processing of prediction-violating stimuli is not obligatory, but task-dependent.

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23.425 The antisaccade task: Sensory- and motor-related costs to oculomotor planning
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The concurrent presentation of a target and remote distractor (> 20°) increases the planning times of stimulus-driven prosaccades (i.e., the remote distractor effect, RDE). In the present investigation, we sought to determine whether antisaccade planning times are similarly influenced by the presentation of a remote distractor. Indeed, the basis for this question stems from the fact that the non-standard mapping between stimulus and response in the antisaccade task provides a basis for determining whether the sensory- or motor-related features of a distractor influence oculomotor planning times. In Experiment 1, participants completed pro- and antisaccades in a condition that entailed a single and exogenously presented target (i.e., control condition) and conditions wherein the target was presented simultaneously with distractors at remote (i.e., contralateral, foveal) or ipsilateral locations relative to the target. Results for prosaccade latencies showed the aforementioned RDE, whereas antisaccade latencies for all distractor locations were increased compared to their control condition counterparts. Experiment 2 involved same basic methods as Experiment 1 with the exception that we precued distractor location to reduce the attentional demands associated with disentangling target and distractor locations at response planning. Results confirmed the findings of Experiment 1 in that antisaccade latencies were increased across each distractor location. Moreover, the antisaccade latency cost was increased when the spatial properties of the distractor were congruent with motor-related task goals. Based on these findings, we propose that the non-standard nature of antisaccades renders a general increase in oculomotor planning times regardless of the distractor's spatial properties. Further, we propose the spatial relations between distractor and movement-related goals elicit an increased inhibition of oculomotor networks than the spatial relations between distractor and veridical stimulus location.

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23.426 The asymmetrical weighting of target eccentricities within a trial block influences antisaccade endpoint bias
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Antisaccades are rapid goal-directed eye movements requiring that a participant saccade mirror-symmetrical to the location of a target stimulus. Notably, antisaccades require top-down control and engage visual metrics that are distinct from their prosaccade counterparts. In keeping with this view, our group has shown that antisaccade endpoints are governed by a perceptual averaging strategy. In particular, endpoint bias for any target within a stimulus-set is influenced by the magnitude of the undershooting bias associated with the stimulus-set's central target. In other words, results suggest that antisaccade endpoints are influenced by relational target properties. To further address this issue, the present study examined whether the asymmetrical weighting of different target eccentricities within a stimulus-set systematically influences the direction (i.e., undershooting vs. overshooting) of antisaccade endpoint bias. To that end, participants (N=14) completed antisaccades (and matched prosaccades) to briefly presented target stimuli in three separate sessions. Target eccentricities in all sessions were 10.5, 15.5, and 20.5°. In the first session (i.e. the control session) participants completed an equal number of trials to each target eccentricity, whereas in the other sessions participants respectively completed five times as many trials to the 10.5° (i.e, proximal weighting condition) and 20.5° (i.e., distal weighting condition) targets. Results for the control session showed that antisaccades across each target eccentricity elicited a reliable undershooting bias. Notably, however, for the proximal weighting condition it was found that antisaccade amplitudes produced an increased undershooting bias to all target eccentricities relative to their control condition counterparts. In turn, the distal weighting condition showed a reduced undershooting bias compared to their control condition counterparts. As such, we propose that the top-down nature of antisaccades elicits a perceptual averaging strategy that bias' a response in the direction of a frequently presented target stimulus.

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23.427 Unidirectional switch-costs in oculomotor control are a result of a stimulus-response updating: Evidence from electroencephalography
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Antisaccades require the top-down suppression of a stimulus-driven prosaccade (i.e., response suppression) and updating of normally direct stimulus-response (S-R) mappings to a context-dependent mirror-symmetrical location. Notably, the top-down control of antisaccades results in a response with longer reaction times (RT) than their prosaccade counterparts. Moreover, recent work by our group has shown the completion of an antisaccade lengthens the RT of a subsequent prosaccade; however, the converse 'switch' does not influence RT (i.e., the unidirectional prosaccade switch-cost). Thus, results demonstrate that response suppression and/or S-R context-updating engenders a residual inhibition of the oculomotor networks which support prosaccade planning. In order to determine whether response suppression and/or S-R context-updating contributes to the unidirectional prosaccade switch-cost we examined the event-related brain potentials (ERPs) associated with oculomotor task-switching. Specifically, we examined whether ERPs attributed to response suppression (i.e., N2) and/or S-R context-updating (i.e., P3) are related to the unidirectional prosaccade switch-cost. To that end, participants alternated between pro- and antisaccade in a randomized task-switching order while concurrently recording electroencephalography data. As expected, prosaccades preceded by antisaccades (i.e., task-switch prosaccades) had longer RTs than prosaccades preceded by prosaccades (i.e., task-repetition prosaccades), whereas the RTs of antisaccades were not modulated by the nature of the preceding task-type. In addition, the amplitude of the P3 – but not the N2 – elicited a reliable difference between task-switch and task-repetition prosaccades, whereas task-switch and task-repetition antisaccades did not yield reliable differences for either ERP component. Thus, RT differences associated with task-switch and task-repetition prosaccades are related to amplitude differences in the P3 waveform. As such, we propose that the unidirectional prosaccade switch-cost is not related to response suppression; rather, results suggest updating an internal mental model related to S-R compatibility engenders a residual inhibition of the oculomotor networks supporting the planning of prosaccades.

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23.428 The latencies of prosaccades are prolonged by both executed and planned (but not executed) prior antisaccades
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Background: Studies that mix trials with prosaccades and antisaccades have shown that there are carry-over effects between one trial and the next. In particular, a preceding antisaccade leads to increased latencies of the following response, particularly if it is a prosaccade. Whether this antisaccade effect results from effects generated in the execution of the antisaccade or possibly in the planning and preparation process is unknown. Objective: We studied whether prolongation of the latencies of subsequent prosaccades after antisaccade trials depended upon execution of the antisaccade or occurred regardless of whether the antisaccade was actually performed. Methods: 9 subjects were tested using blocks of randomly ordered prosaccades and antisaccades. An instructional cue at fixation indicated whether a prosaccade or antisaccade was required when the target appeared 2 seconds later. On 20% of the antisaccade trials, the target did not actually appear (antisaccade cue/no-target trials). We analysed the latencies of all correct prosaccades or antisaccades that were preceded by correctly executed trials. Results: As expected the latencies of prosaccade trials preceded by prosaccades were 20ms shorter (mean 189ms) than the latencies of prosaccade trials preceded by antisaccades (mean 209ms). Prosaccades preceded by trials where antisaccades were cued but not executed because the target did not appear also showed prolonged latencies (mean 214ms). These differed from the latencies of trials with preceding prosaccades but not from those of trials with preceding antisaccades. Conclusion: The effects of a prior antisaccade in prolonging the latencies of subsequent saccades is generated by the planning of the antisaccade. This may reflect persistence of the known pre-target preparatory activity seen in neural recordings of the superior colliculus and frontal eye field.

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23.429 **Influence of task switching on inhibition of return and scan paths**
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Fixation location during scene viewing can be predicted by salience or task relevance, with the most salient or relevant regions fixated first. To ensure that fixation does not perseverate on the most conspicuous region, the prevailing solution is a mechanism that decreases the likelihood of returning to previously fixated regions, i.e., inhibition-of-return (IOR). Previous work examining the generality of IOR indicates a dependency on viewing task, finding IOR for search tasks but facilitation-of-return (FOR) for memory, evaluation, and free-view tasks. If a mechanism acting as a short-term memory for recently fixated locations inhibits return for some tasks and facilitates return for others, then it might be a component of task-set (i.e., representation of task-relevant stimuli and responses and the corresponding stimulus-response rules) and, therefore, susceptible to influence from a previous task. To investigate this possibility, we examined whether task repetitions and switches influence IOR and scan paths. Participants performed search, memorization, and evaluation tasks in either blocked or mixed order. Analysis of saccadic reaction times in blocked trials to probes appearing either at previously fixated locations or at novel locations replicated evidence of IOR during scene search and FOR during scene memorization and evaluation. This pattern generalized to mixed trials when the task on the previous trial repeated. When the task on the previous trial differed, FOR was still observed during memorization and evaluation but was now also observed during search. Analysis of scan paths largely agreed with recent work in showing above chance return probabilities to previous fixation locations. An important exception, however, was for repeated scene search in mixed task trials. Here, return probabilities were at chance and there was a large spatial bias away from previous fixation locations. We conclude that the visual-saccadic system is flexible and depends on both the current and previous task.

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23.430 **Modulation of alpha power by eye state during kinesthetic motor imagery (KMI) of a newly learned dance sequence in experts**
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Changes in alpha band power (8-13Hz) with eye state has been well documented (i.e., closing or opening the eyes; Berger, 1939), with closing increasing alpha power (synchronization) and opening decreasing alpha (desynchronization). With increased cognitive load, similar changes have been demonstrated for motor imagery, with alpha desynchronization in recruited areas and synchronization in task-irrelevant areas (Pfurtscheller et al., 1999). However, the interaction of eye state and cognitive load on alpha power has never been examined in a single study. In a sample of n=30 subjects trained to move to music (dance, figure skating, and gymnastics), continuous electroencephalography (EEG) activity was recorded during three tasks: (i) baseline accompanied by music, (ii) observational learning of a brief dance sequence, and (iii) kinesthetic motor imagery (KMI) of the newly learned dance. KMI involves imagining oneself performing movement from a first-person internal perspective, and was examined in two conditions dependent on eye state. Our results confirm a main effect of higher alpha power with eyes closed ($F(1,29)=36.2$, $P<0.001$, $\eta2=0.56$) and an interaction with eye state and cognitive load ($F(5,145)=9.4$, $P<0.001$, $\eta2=0.24$): alpha power was lower during KMI relative to baseline when eyes are closed in occipital and right parietal recording sites ($P<0.05$), but was significantly greater during KMI in the eyes open condition in all but left temporal recording sites ($P<0.01$). Most importantly, subjective ratings of clarity and vividness of KMI were significantly reduced during the eyes open condition ($P<0.01$). Together, these results suggest that both alpha power and the ability to effectively engage in KMI are modulated by eye state. We provide evidence for alpha synchronization and diminished KMI ability relative to baseline when eyes are open, and that this trend is reversed when eyes are closed. This may explain why people will usually close their eyes during mental rehearsal.

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23.431 **Actions in the Eye**
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Early qualitative eyetracking studies pioneered by Yarbus revealed strong inter-viewer consistency and task influence. Recent advances in eyetracking technology open up prospects to investigate these effects on large scale datasets acquired under specific task constraints and to apply machine learning techniques to human visual saliency and eye movement prediction, with various practical applications. We present experimental and computational modeling work at the incidence of human visual attention and computer vision, with four components. First, we introduce three novel large scale datasets (exceeding 1.7 million fixations) containing eye movement annotations for real world images and video, for action and context recognition tasks. Second, we analyze quantitatively inter-subject consistency and task influence on visual patterns. We use clustering and Hidden Markov Models to automatically locate areas of interest using eyetracking data. Scanpaths are then viewed as chains of characters and compared using string matching algorithms (Needleman-Wunsch). Our analysis reveals strong spatial and sequential inter-subject consistency. Third, we apply human eye movement data for computer-based action recognition. We compare computer vision spatio-temporal interest point image sampling strategies to human fixations and show their potential for automatic visual recognition. Spatio-temporal Harris Corners are poorly correlated with human fixations, while interest point operators derived from empirical saliency maps outperform existing computer vision operators for action recognition. We use SVMs to train effective top-down models of human visual saliency in conjunction with Histogram of Gradient features and use them within end-to-end bag-of-words computer-based visual action recognition systems to achieve state-of-the-art results in computer vision benchmarks. Fourth, for sequential eye movement prediction, we learn task-sensitive reward functions from eye movement data within inverse optimal control models. We find our models to be superior to existing bottom-up scanpath predictors. We hope that our work will foster further communication, benchmarks and methodology sharing between human and computer vision.

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23.432 **Executive functioning can mediate age-related changes in oculomotor attentional disengagement**
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Successful goal-directed behavior depends on efficient disengagement of attention. Certain brain lesions (Posner et al., 1984) and aging can cause a "disengagement deficit" (Cosman et al., 2011). The patterns of decline can provide insights on how attention demanding real-world behaviors (e.g. automobile driving) change over the lifespan. We used a cross-sectional experimental design to characterize how efficiency of attentional disengagement influences oculomotor behavior. We compared 15 college-aged and 15 older adults (mean age: 78 [4.13]) on a variant of the "gap" paradigm. Participants were asked to saccade to a target onset in the periphery. In gap trials, a central fixation spot was extinguished before target onset (eliminating the need to disengage attention). In no gap trials, fixation remained, but its color changed before target onset, controlling for general alerting effects that might accompany fixation offset. Saccadic reaction times (SRTs) are typically lower in gap trials (Saslow, 1967), as visuospatial attention is reflexively disengaged when the fixation target is removed, facilitating the ensuing saccade (Fischer & Weber, 1993). Disengagement deficits should be more evident in no gap trials (when the fixation target remains), as higher-level control processes required for disengagement of attention become less efficient with advancing age (Cashdollar et al., 2013). In this vein, we observed a significant interaction between gap condition and age group. Older adults showed a significantly ($p<.0001$) greater gap effect (95.6 [42.8] ms) compared to young adults (41.3 [24.5] ms), with the greatest slowing occurring in the no gap condition. Two follow-up experiments, investigated how cognitive load manipulations (VSTM or executive working memory) affect oculomotor disengagement. Results showed executive working memory loading selectively slowed disengagement. The pattern of findings suggest that variations in disengagement efficiency associated with aging can influence oculomotor behavior, and that individual differences in executive control processes mediate disengagement functions.

23.433 **Infant Saccadic Behavior Influenced by Novelty and Familiarity of Stimuli in the Periphery** Lisa Cantrell[1](cantrell@indiana.edu), Richard Veale[1], Linda Smith[1]; [1]Indiana University

Both endogenous and exogenous factors influence whether and in what direction humans shift visual attention. Early in the infant system, however, environmental factors of saliency as well as motor reflexes appear to play a key role in visual behavior as infants make saccades in the direction of movement or regions of high contrast (Aslin & Salapateck, 1975; Banks & Gingsburg, 1985) and saccade even in total darkness (Haith, 1980). By 4 months, infants show evidence of using learned cues to guide saccades (e.g., Johnson, Posner, & Rothbart, 1991), suggesting that top-down processes also play a role. Here we ask if the recognition of novelty and familiarity in the peripheral areas of the visual field also guide infants' eye movements. Eighteen infants, age 6-8 months, were presented familiar and novel objects in their periphery at 10 degrees from center. Initial saccades to these objects as well as total time spent looking at the objects was measured. Results showed that, although infants preferred to fixate a longer total time on familiar items, initial saccades were primarily guided by a left spatial field bias that interacted with the tendency to make first saccades to novel objects. These preliminary results suggest that saccadic behavior in infants at this age are still highly determined by automatic motor responses, as a left-side bias has been suggested to be the result of hemispheric lateralization that may result in a default for initial visual scanning of items or scenes--at least in young infants (e.g., Guo, Meints, Hall, Hall, & Mills, 2009); however, the observation that this bias can be shifted by manipulating novelty in the visual scene demonstrates that infant saccadic behavior is also driven by a gravitation towards novel information in the environment— and this influence occurs at the very short time-scales over which saccades occur.

23.434 **Attachment Style Influences Saccades** Jessica A. Maxwell[1](jessica.maxwell@mail.utoronto.ca), J. Eric T. Taylor[1], Jay Pratt[1], Penelope Lockwood[1]; [1]University of Toronto

The present research examined how attachment style (whether one seeks or avoids closeness in relationships) affects saccadic latency away from faces displaying emotion. Research on attachment shows that high anxiety individuals are particularly attuned to negative emotional stimuli, whereas those high in avoidance often disengage from emotional stimuli (e.g. Mikulincer et al., 2000). However, there has been mixed evidence as to whether individuals high in avoidance automatically attend less to emotional stimuli, and whether they are particularly less sensitive to positive emotions (e.g. Fraley et al., 2006; Dewitte et al., 2007; Vrticˇka et al., 2008), as positive emotions may convey intimacy cues that individuals high in avoidance seek to avoid. Further, it remains unclear whether such differences affect other systems that are sensitive to emotion stimuli, such as the oculomotor system. Subjects were presented with a face displaying either fear, happiness or a neutral expression, or a non-face (oval object) control, and made speeded saccades toward a peripheral target. Results indicate that, as predicted, individuals high in attachment anxiety made quicker saccades following all emotion faces, relative to those lower in attachment anxiety, and relative to control trials. Conversely, individuals with low and high avoidance differed only saccadic latency from happy faces, such that those high in avoidance were slower to respond. Within the non-face control condition, we did not observe differences based on attachment style, suggesting that the attachment differences in saccadic reaction times did not generalize to non-face stimuli. Taken together, these results suggest that attachment style produces differential saccadic latencies to various emotions, consistent with attachment theory predictions. This suggests that even at such an automatic level of responding, those high in attachment anxiety are hypersensitive to emotional stimuli, whereas those high in avoidance are hyposensitive to positive emotions.

23.435 **The sensory identification of word centers during reading: A Bayesian model** André Krügel[1](kruegel@uni-potsdam.de), Ralf Engbert[1]; [1]Department of Psychology, University of Potsdam

Human interactions with the environment require movements towards spatially extended objects. For many situations there would be good reasons to aim at object centers in order to maximize the probability to hit the target. For example, saccadic eye movements during reading aim at word centers. However, it is unclear how word centers are localized by the visual system. Furthermore, it has been demonstrated that the computation of the word center during reading is modulated by the distance of the target word from the launch site (McConkie et al., 1988, Vision Res) and by skipped words (Krügel & Engbert, 2010, Vision Res). We present a Bayesian model of saccade planning, which makes explicit assumptions about the visual processes that translate the spatially distributed information provided by a peripheral target word into an estimate of the word center. We assume that the word center is computed from sensory measurements of inter-word spaces and that the sensory information is integrated with a-priori knowledge according to Bayes' rule. Based on a large corpus of eye-movement recording from a normal reading task we demonstrate that our model simultaneously accounts for the effects of saccades' launch-site distance and saccade type during reading. Our oculomotor modelling framework is important for current models of saccade generation in reading and other visual-cognitive paradigms like search and scene perception.

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23.436 **Effects of perceptual expertise in detecting letter transpositions on QWERTY keyboards** Carl M. Mann[1](carl.mann@soton.ac.uk), Valerie Benson[1], Nick Donnelly[1]; [1]University of Southampton

The role of expertise in visual search has largely been explored using medical images. Typically radiographers search for anomalies in human anatomical structures. In medical imaging, targets are often ambiguous, generating high levels of misses/false alarms. Expertise is also restricted to a specific sub group making experimentation challenging. Together, these conditions make the study of perceptual expertise difficult. Here, we explore whether visual expertise effects occur in the identification of letter transpositions on QWERTY computer keyboards in an eye-movement study. Standard QWERTY keyboards follow a structure defined by convention that allows for simple manipulations in layout. By transposing letters we created a set of keyboards, where deviations from the normal arrangement could be graded as low, medium or high. Expertise was determined by performance on a typing speed test. Experts were defined as typing at or more than 60 words per minute and novices were defined as typing at 50 words per minute or less. Participants performed a go/no-go normal/manipulated keyboard decision task responding only when manipulated keyboards were presented. We recorded behavioural response time and accuracy measures in addition to eye movements. The results showed experts and novices to be different in accuracy but not response time. Crucially, experts were faster to detect manipulated regions than novices, a difference that increased with extent of manipulation. Additionally, experts spent less verification time fixating the transpositions themselves. We suggest that experts can use gist to detect deviations from the standard QWERTY keyboard arrangement. While a novel finding in its own right, this finding mimics other effects of perceptual expertise reported in the literature. Demonstrating effects of perceptual expertise in this stimulus domain allows future studies to more readily parameterize effects of perceptual expertise.

23.437 **Eye Movements of Dry Eye (DE) Patients During Reading.** William Ridder, III[1](wridder@ketchum.edu), Eric Borsting[1], Pat Yoshinaga[1], Hoang Vy Ha[1], Stephen Ridder[1]; [1]Southern California College of Optometry at Marshall B. Ketchum University

Introduction: A recent epidemiological study indicated that DE patients report that reading is a difficult task (odds ratio 3.64, $p < 0.0001$). In addition, studies have demonstrated that DE patients read slower than normal controls. However, there are no reported studies that have monitored eye movements of DE patients while they read. The purpose of this study was to investigate if specific eye movement parameters are altered during reading in DE patients. Methods: Seventeen subjects took part in this study (10 DE (age 63.2 ± 6.16) and 7 normal controls (age 61.3 ± 7.01)). All subjects had a complete eye exam with DE work up. DE patients had both subjective and objective signs of a DE in compliance with the recommendations of the 2007 International Dry Eye Workshop. The Tobii TX300 Eye Tracker monitored eye movements (saccades, fixations, regressions, and blinks) during reading. The Wilkins Rate of Reading Test was used to determine reading rate. Results: There were no significant differences between DE patients and normal controls for saccade amplitude, saccade velocity, fixation time, number of saccades or fixations, or number of regressions (all p values > 0.05). The reading rates were also not different between the groups (DE = 152.6 ± 13.4 wpm, Control =159 ± 13.2 wpm, p = 0.34). The DE patients had more total blinks (DE = 21.0 ± 8.18, Control = 5.29 ± 2.69, $p < 0.001$) and a shorter inter-blink interval (DE = 3.3 ± 2.04 sec, Control = 14.9 ± 8.54 sec, p = 0.013) than the normal controls. Conclusions: The increased number of blinks and the shorter inter-blink interval while reading may result in a slower reading rate and a greater difficulty reading for DE subjects.

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23.438 **Using RSVP and Eye Movement Recording to Determine Usefulness of Information Content Definitions as Predictor for Reading Speed** Yannik T. H. Schelske[1](y_schels@cs.uni-kl.de), Tandra Ghose[2], Thomas M. Breuel[1]; [1]Department of Computer Science, University of Kaiserslautern, Germany, [2]Department of Psychology, University of Kaiserslautern, Germany

It is well established that reading speed is affected by the information-content of words (Rayner et. al). There exist many different definitions of information-content. We used the normal and the maximal reading speed for a given sentence as measures to determine the usefulness of different information-content definitions. The normal reading speed of a participant was determined by recording the eye movements during a self-paced reading task (reading speed was actively controlled by the participant), the maximal reading speed of a participant was determined by adjusting the display duration of words in a staircase-based rapid serial visual presentation (RSVP) task (reading speed was passively controlled by the experimenter). The information-content of the words in the sentences were determined in multiple ways, namely based on transitional probability (McDonald & Shillcock, 2003) calculated from the British National Corpus (BNC), based on contextual predictability calculated from a cloze task (Frisson, Rayner & Pickering, 2005) and based on different n-gram probabilities calculated from the Google Books Corpus (GBC). We found that the eye movements in the self-paced reading task, indicative for the normal reading speed of the subject, were best predicted by information-content definitions which were based on contextual probability (i.e. broad semantic relationship between target word and the whole of the sentence), and that in contrast, display durations in the RSVP task, were best predicted by information-content definitions based on n-gram probabilities (i.e. narrow syntactical relationship between target word and a small word neighborhood). Our interpretation of these findings is that for early stages in the visual recognition process of words more simple characteristics (namely n-gram probabilities) are exploited whereas more complex characteristics namely contextual probability are later accessed to facilitate the recognition. We therefore suggest choosing the appropriate information-content definition to help understand the limitations of the reading process at different stages better.

Acknowledgement: This work was funded by a Marie Curie grant (CIG#293901) from the European Union awarded to TG.

23.439 **Predicting Visual Awareness by Looking into Eye Fixations** Chengyao Shen[1,4](scyscyao@gmail.com), Danyang Kong[2], Shuo Wang[3], Qi Zhao[4]; [1]NUS Graduate School for Integrative Science and Engineering (NGS), [2]Cognitive Neuroscience Laboratory, Duke-NUS Graduate Medical School, [3]Computation and Neural Systems, California Institute of Technology, [4]Department of Electrical Computer Engineering, National University of Singapore

Despite the great popularity and convenience of eye tracking experiments, a well-known problem is its limited power in reading the internal mental status. For example, the raw fixation data do not tell whether the user is aware of the contents where fixations landed. Most studies simply assumed that what is "fixated" is what is "seen", which is not always true. To predict visual awareness, here we zoomed in each fixation in a visual search task and built a model to predict user awareness in a fixation-by-fixation basis. We first conducted a visual search task where 20 visual search arrays containing separate objects were designed and eye movement data from 11 subjects were collected. The visual search paradigm provided the ground truth of visual awareness (based on whether subjects pressed the key to indicate target detection) for learning a prediction model. We then extracted a number of eye fixation features including previous and current fixation duration, normalized pupil size, fixation spatial density, microsaccade number, and previous saccade magnitude. These features were fed into a linear Support Vector Machine (SVM) to predict user awareness of target detection. After cross validation, we obtained accuracy levels of 92.2% for non-recognized fixations on target and 86.5% for recognized fixations on target. SVM also identifies the most important features in the prediction as fixation spatial density, current fixation duration, and previous saccade magnitude. The results show that the proposed eye fixation features and the machine learning technique can predict visual awareness in a high confidence level. The effective prediction of visual awareness suggests that eye fixations contain rich information and is useful in revealing cognitive status.

Eye movements: Fixational

Saturday, May 17, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

23.440 **Microsaccades scan highly informative image areas**
Michael McCamy[1,2](mike.mccamy@gmail.com), Jorge Otero-Millan[1,3], Leandro Luigi Di Stasi[1,4], Stephen Macknik[1,5], Susana Martinez-Conde[1]; [1]Department of Neurobiology, Barrow Neurological Institute, Phoenix, AZ, USA, [2]School of Mathematical and Statistical Sciences, Arizona State University, Tempe, AZ, USA, [3]Department of Signal Theory and Communications, University of Vigo, Vigo, Spain, [4]Mind, Brain, and Behavior Research Center (CIMCYC), University of Granada, Granada, Spain, [5]Department of Neurosurgery, Barrow Neurological Institute, Phoenix, AZ, USA

The visual system is constrained by limitations that challenge the efficient and unambiguous encoding of commonly encountered signals. To understand how human vision overcomes these hurdles, we must consider its sampling method (top-down and bottom-up guided saccades and fixations) as well as the statistics of the visual environment. Previous studies have shown that image statistics can influence fixation locations, but their effects on the production of microsaccades during fixation are unknown. Indeed, no research has shown a role of microsaccades in information acquisition during visual scanning. Microsaccade production and information acquisition could be linked in a variety of ways: 1) Microsaccades may sample image regions where information content is high. If so, more informative regions should trigger higher microsaccade rates than less informative regions; 2) Microsaccades may instead extract information from image regions where information content is low. If so, less informative regions should trigger higher microsaccade rates; 3) Microsaccades may not be related to information acquisition, in which case microsaccade rates should be equivalent in more and less informative regions. To determine which possibility is correct, we must first specify more versus less informative image regions. We defined more versus less informative regions in terms of fixation consistency across observers, so as to account for both bottom-up and top-down influences on image exploration. We then compared the characteristics of fixations in more versus less informative regions. We also analyzed the classical statistics of image patches around fixations as a function of informativeness and microsaccade production. Viewers generated more microsaccades and fixated for longer periods on more informative image regions. Such regions were less redundant in terms of their contrast, entropy, and correlation. Further, microsaccade production was not fully explained by fixation duration, suggesting that the visual system specifically employs microsaccades to heighten information acquisition from highly informative image regions.

Acknowledgement: National Science Foundation (Awards 0852636 and 1153786 to SM-C)

23.441 **Influence of Microsaccades on Contrast Sensitivity: Theoretical Analysis and Experimental Results** Naghmeh Mostofi[1](n-mostofi@bu.edu), Marco Boi[1], Michele Rucci[1,2]; [1]Department of Psychology, Boston University, Boston, MA 02215, [2]Graduate Program in Neuroscience, Boston University, Boston, MA 02215

The visual functions of microsaccades have been the subject of intense debates. We have recently shown that microsaccades precisely relocate the preferred retinal locus according to the task demands (Ko et al., 2010), bringing the stimulus on the most suited retinal region within the foveola (Poletti et al., 2013). However, it has long been questioned whether temporal transients caused by microsaccades are also beneficial. To address this question, we first conducted time-frequency analyses of the retinal input relative to the occurrence of microsaccades. We show that microsaccades contribute slightly more temporal power than ocular drift (the incessant intersaccadic eye movement) for stimuli below 10 cycles/deg suggesting a potential benefit in the low-frequency range. We then measured the influences of microsaccades on contrast sensitivity in a 2AFC experiment in which subjects reported the orientation (±45°) of a Gabor stimulus at either 0.8 or 10 cycles/deg. We show that, in agreement with theoretical predictions, contrast sensitivity slightly improved in the trials with one or more microsaccades compared to drift-only trials. As predicted, this effect was limited to the low spatial frequency stimulus. No benefit of microsaccades on contrast sensitivity was observed with a 10 cycles/deg grating. In both cases, however, all subjects exhibited a substantial suppression of microsaccades (approximately 70%) during the period of stimulus presentation. This suppression was also present with the low spatial frequency grating, in spite of the small perceptual benefit of microsaccades. In sum, our theoretical and experimental results show that, even though microsaccadic transients slightly improve sensitivity

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to low spatial frequencies, observers do not normally take advantage of them. This behavior makes sense with the localized stimuli of natural environment, where the detrimental consequences of bringing the preferred fixation locus away from the region of interest would outweigh the small perceptual benefit resulting from microsaccade temporal modulations.

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23.442 **The characteristics of microsaccadic eye movements varied with the change of strategy in a match-to-sample task.** Claudio Simoncini[1](claudio.simoncini@univ-amu.fr), Anna Montagnini[1], Laurent U. Perrinet[1], Guillaume S. Masson[1]; [1]Institute de Neuroscience de la Timone, CNRS & Universite Aix-Marseille

Under natural viewing conditions, large eye movements are interspace by small eye movements (microsaccade). Recent works have shown that these two kinds of eye movements are generate by the same oculomotor mechanisms (Goffart et al., 2012) and are driven from the same visual information (Simoncini et al., VSS 2012 abstract). These results seem to demonstrate that microsaccade and saccade represent a continuum of the same ocular movement. However, if the role played in vision perception by large saccades is clearly identified, the role of the microsaccade is not clearly defined. In order to investigate the role of microsaccade, we measured pattern discrimination performance using an ABX match-to-sample task during the presentation of 1/f natural statistics texture where we varied the spatial frequency contents. We compared perceptual performance with eye movements recorded during the task. We found that the rate of microsaccadic movements changed as a function of the subjects task strategy. In particular, in the trials where the perception of the difference between the stimuli was simple (low spatial frequency) the subjects used the information provided by all the stimuli to do the task and the microsaccadic rate for all the stimuli (ABX) was the same. However, when the perception of the difference between the stimuli was harder (for instance for high spatial frequency), the subjects rather used the information provided by the last two stimuli only and the microsaccadic rate for the image BX increased respect at the image A. These results demonstrate that microsaccadic eye movements also play a role during the analysis of the visual scene and that such experiments can help decipher their participation to perception of the scene. Goffart L., Hafed Z.M., Krauzlis R.J. 2012. Visual fixation as equilibrium: evidence from superior colliculus inactivation. (31) 10627-10636.

23.443 **Spatial Distribution of Slow Involuntary Fixational Eye Movements is Related to the Occurrence of Microsaccades and Their Shapes** Debashis Sen[1](dsen.soc.nus@gmail.com), Chengyao Shen[2,3], Mohan Kankanhalli[1], Zhi Yang[2], Qi Zhao[2]; [1]School of Computing, National University of Singapore, [2]Department of Electrical and Computer Engineering, National University of Singapore, [3]NUS Graduate School for Integrative Science and Engineering

During fixations, involuntary miniature fixational eye movements (FEMs) are generated which include microsaccades (fast FEMs), drifts and tremors (slow FEMs), with the slow FEMs occurring between microsaccades. Here we examined the relationship between microsaccades and their temporally-neighboring slow FEMs. We first examined how the spatial distributions of the slow FEMs relate to the occurrence of microsaccades. Further, we investigated how they are related to the shapes of microsaccades. We define a microsaccade's shape as the ratio (R) of its path length to the spatial distance it covers, with a larger R indicating less linearity. In the experiment, subjects were instructed to fixate at a randomly positioned dot (0.26°) and press any key on its disappearance, during which an irrelevant cue (1°) appeared around the dot for two seconds. The cue contained luminance, equiluminant color, or luminance+color contrasts. From the FEMs during the cue onset, we measured variance of three types of sampled slow FEM cluster: (1) cluster of those preceding a microsaccade, (2) cluster of those when no microsaccade occurs, and (3) cluster of those preceding and succeeding a microsaccade combined together. We find that the variance of the cluster when no microsaccade occurs is statistically larger ($p<.001$) than that preceding a microsaccade, suggesting that the extent of spatial area covered by slow FEMs preceding a microsaccade is employed by the mechanism that generates microsaccades. Furthermore, for a microsaccade with a larger R (mostly nonlinear overshoot burst followed by returning movement), the variance of the cluster combining slow FEMs just before and after it, is statistically smaller ($p<.001$). Therefore, microsaccades with larger R are more likely to occur for fixation correction, as such an intention should lead to a smaller variance of the combined cluster. Microsaccades with smaller R occur most likely for other purposes, such as sampling.

23.444 **Characteristics of square-wave jerks in the macaque monkey** Francisco Costela[1,2](francisco.costela@gmail.com), Jorge Otero-Millan[1,3], Michael McCamy[1], Stephen Macknik[1,4], Xoana Troncoso[5], Ali Najafian[1], Susana Martinez[1]; [1]Department of Neurobiology, Barrow Neurological Institute, Phoenix, AZ, USA, [2]Interdisciplinary PhD Program in Neuroscience, Arizona State University, Tempe, AZ, USA, [3]Department of Signal Theory and Communications, University of Vigo, Vigo, Spain, [4]Department of Neurosurgery, Barrow Neurological Institute, Phoenix, AZ, USA, [5]Division of Biology, California Institute of Technology, Pasadena, CA, USA

Saccadic intrusions, predominantly horizontal saccades that interrupt accurate fixation, include square-wave jerks (SWJs; the most common type of saccadic intrusion), which consist of an initial saccade away from the fixation target followed, after a short delay, by a ''return saccade'' that brings the eye back onto target. SWJs are present in most human subjects, but are prominent by their increased frequency and size in certain parkinsonian disorders and in recessive, hereditary spinocerebellar ataxias. Here we set out to determine the characteristics of SWJs in normal rhesus macaques during attempted fixation. We found that primate and human SWJs shared comparable features overall, but the likelihood of a given saccade being part of a SWJ was lower for primates than for humans

23.445 **Hypobaric hypoxia increases intersaccadic drift velocity** Leandro L. Di Stasi[1,2,3](distasi@ugr.es), Raúl Cabestrero[4], Michael B. McCamy[1], Francisco Ríos[5], Andrés Catena[6], Pilar Quirós[4], Jose A. Lopez[5], Carolina Saez[5], Stephen L. Macknik[7,1], Susana Martinez-Conde[1]; [1]Department of Neurobiology, Barrow Neurological Institute, Phoenix, AZ, USA., [2]Cognitive Ergonomics Group, Mind, Brain, and Behavior Research Center (CIMCYC). University of Granada, Granada, Spain., [3]Joint Center University of Granada - Spanish Army Training and Doctrine Command, Spain., [4]National University of Distance Education, Madrid, Spain., [5]Spanish Defence Aero-medical Center (C.I.M.A.), Madrid, Spain., [6]Learning, Emotion, and Decision Group. Mind, Brain, and Behavior Research Center (CIMCYC). University of Granada, Granada, Spain., [7]Department of Neurosurgery, Barrow Neurological Institute, Phoenix, AZ, USA.

Hypoxia, defined as decreased availability of oxygen in the body's tissues, can lead to dyspnea, rapid pulse, syncope, visual dysfunction, mental disturbances such as delirium or euphoria, and even death. It is considered to be one of the most serious hazards during flight. Thus, early and objective detection of the physiological effects of hypoxia is critical to prevent catastrophes in civil and military aviation. The few studies that have addressed the effects of hypoxia on objective oculomotor metrics have had inconsistent results, however. Thus, the question of whether hypoxia modulates eye movement behavior remains open. Here we examined the effects of short-term hypobaric hypoxia on the velocity of saccadic eye movements and intersaccadic drift of Spanish Air Force pilots and flight engineers, compared to a control group that did not experience hypoxia. Saccadic velocity decreased with time-on-duty in both groups, in correlation with subjective fatigue. Intersaccadic drift velocity increased in the hypoxia group only, suggesting that acute hypoxia diminishes eye stability, independently of fatigue. Our results suggest that intersaccadic-drift velocity could serve as a biomarker of acute hypoxia. These findings may also contribute to our understanding of the relationship between hypoxia episodes and central nervous system impairments.

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23.446 **Fixation strategies revealed by the retinal imaging** Girish Kumar[1](girish.kumar@berkeley.edu), Susana Chung[1,2]; [1]School of Optometry, University of California, Berkeley, [2]Vision Science Graduate Program, University of California Berkeley

It is well known that the resolving power of the retina is not uniform. Visual acuity is highest at the fovea and decreases at greater eccentricities. It is possible that normal subjects would use different locations on the retina to fixate at targets that have different resolution requirements, rather than always fixating using the retinal locus with the highest resolution. To test this hypothesis, we recorded the fixation behavior of 4 subjects using a Scanning Laser Ophthalmoscope (SLO) while simultaneously presenting fixation targets. This experimental setup allows us to determine the precise retinal location of the stimulus. We used two different types of stimuli: square dots that were 4, 8 and 16 arc minutes in size as well as letters that were 10, 20 and 40 arc minutes in height. Letters were presented singly or in

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groups of three (trigrams) or five (pentagrams) and were rendered using the Sloan font set. Subjects were instructed to fixate at the center of the target (square, single letter, trigram, pentagram) which was presented randomly within the 100 SLO imaging raster for 10 seconds. All sizes for each stimulus type were repeated 3 times. Videos of the subject's retina during each trial were recorded and eye movements were extracted from these videos using a cross-correlation technique. The fixation variability (measured using Bivariate Contour Ellipse Area (BCEA)) and retinal locus of fixation were calculated from the extracted fixation eye movements and compared across subjects. Fixation variability ranged from 0.04 to 0.76 deg2 across the different fixation conditions. Analysis of Variance did not reveal any significant statistical differences between conditions. Our results lead us to infer that for the range of stimulus sizes used in our study, normal subjects do not adopt different fixation strategies based on resolution requirements.

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23.447 **Non-Foveating Saccades and Fixations** Helga Mazyar[1](mazyar@usc.edu), Bosco Tjan[1,2]; [1]Neuroscience Graduate Program, University of Southern California, Los Angeles, [2]Department of Psychology, University of Southern California, Los Angeles

The human oculomotor system makes saccades to bring objects of interest to the fovea. Losing foveal vision often leads to the adoption of a preferred retinal locus (PRL) for fixations, with saccades re-referenced to it. Factors underlying the development of a PRL are not well understood. We test the hypothesis that gaze control for saccades and fixation without a fovea is achieved through a minimum modification to the existing oculomotor plan. Using a gaze-contingent display, we asked normally sighted subjects to move a green ring, 6° in radius and centered at the fovea, to make contact with a small disc that appeared at a random location on the display in each trial. The subject had to maintain contact between the ring and the disc for 500 ms before the disc was dismissed and a new trial began. The inside of the ring was opaque to simulate a central scotoma. Four of the five subjects consistently used only a small region of the ring to make contact, even when the target disc was closer to another point on the ring. This development of a PRL was spontaneous and fast (<3 hrs, over a course of few days). Furthermore, the same PRL was retained several days after the experiment when the subjects were asked to "look at" a jumping target with a simulated central scotoma. In contrast, when the same subjects performed the task using a mouse to control the ring, they generally used the point on the ring closest to the target disc to make contact. Hence, while hand movements followed the shortest-distance strategy, eye movements opted for a fixed point and developed a PRL. It appears that the oculomotor system is highly constrained and can only adopt a constant offset to its existing motor plans for foveation.

Acknowledgement: NIH EY017707

23.448 **Investigating task-dependent and stimulus-driven mechanisms of fixational saccades when detecting or discriminating a stimulus** Sara Spotorno[1](sara.spotorno@univ-amu.fr), Anna Montagnini[1]; [1]Institut de Neuroscience de la Timone, CNRS and Aix-Marseille University, France

Previous studies have indicated that fixational saccades are influenced by the spatial frequency content of the stimulus (Simoncini et al., 2012), enhance processing of stimuli of high spatial frequency (Rucci et al., 2007) and may be modulated in order to improve performance in high-acuity tasks (Ko et al., 2010). We further investigated the adaptive nature of fixational saccades in human observers in two classical psychophysical tasks with a two-interval forced choice paradigm. The first task required detection of a vertical or tilted grating characterised by one of three spatial frequencies, one of four contrasts and embedded in pink or white noise (with high or low contrast). The second task required frequency discrimination between two high-contrast tilted gratings in high-contrast or low-contrast pink noise. Findings revealed that the pattern of fixational saccades was participant-specific. Saccadic amplitude varied slightly between frequencies, but was similar between tasks and display types (gratings with noise vs. noise-only in the detection task, reference vs. test in the discrimination task). However, in both tasks, smaller amplitude and fewer saccades were found in low-noise than in high-noise displays. This effect was enhanced when detecting low-contrast gratings. In the detection task saccadic amplitude was also reduced with high-contrast gratings compared to low-contrast gratings, but only with high-noise. These findings indicate that saccadic amplitude was inversely correlated with the degree of stimulus visibility. Grating orientation did not affect saccade direction in either task. Moreover, no consistent differences in saccade amplitude and saccade number were observed depending on performance accuracy. Overall, our results challenge the idea that fixational saccades can generally be modulated adaptively by either task-dependent mechanisms or by stimulus-driven mechanisms related to the frequency spectrum of the stimulus. They suggest instead that idiosyncratic factors, task context and stimulus visibility can have an importance that has been previously underestimated.

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Face perception: Neural mechanisms

Saturday, May 17, 8:30 am - 12:30 pm
Poster Session, Pavilion

23.501 **Increasing extent of category selectivity with increasing power.** Joseph Arizpe[1,2](arizpej@mail.nih.gov), Dwight Kravitz[1,3], Emily Bilger[1,4], Chris Baker[1]; [1]Laboratory of Brain and Cognition, NIMH, NIH, [2]Institute of Cognitive Neuroscience, University College London, [3]Psychology Department, Columbian College of Arts and Sciences, The George Washington University, [4]Cooper Medical School, Rowan University

Functional localization of visual category-selective brain regions (e.g. face-selective FFA, scene-selective PPA, object-selective LOC) with fMRI has suggested the existence of discrete, functionally distinct regions of cortex, easily identifiable with single five-minute scans. These regions are implicitly assumed to have sharp boundaries and increasing resolution could potentially increase the precision of these boundaries. We investigated the distribution and number of scene-, object-, and face-selective voxels throughout cortex within individual subjects across a range of resolutions (1.2, 1.6, 2 and 3 mm isotropic voxels) at both 3T and 7T. To maximize power we used multiple five-minute localizer runs (up to 16 per subject per resolution). If such regions are discrete, then the number of selective voxels identified should asymptote with increasing power. However, we found that the number of selective voxels increased almost linearly as a function of number of localizer runs, regardless of the categories used, for both 3T and 7T and for both smoothed and unsmoothed data. With high power, the face- and scene-selective voxels appear to form two parallel streams emerging from central and peripheral early visual cortex, respectively. At high resolution at 7T, where medial-temporal lobe susceptibility artifacts are minimized, these streams extend into the anterior temporal lobe where scene selectivity terminates in the rhinal cortices and face selectivity in more lateral aspects of the anterior temporal lobe. Within these streams there are peaks of selectivity that may co-localize with large draining vessels. Thus, the relative strength and topography of category selectivity across the streams may be driven in part by vascular anatomy and not just cortical specialization. These findings highlight limitations of using contrasts to investigate the topography of selectivity, emphasize the difficulty of interpreting null results in fMRI, and argue for richer descriptions of the type of processing across cortical regions.

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23.502 **Representations of individual faces in the right anterior temporal lobe are invariant across different partial views of faces.** Stefano Anzellotti[1,2](anzellot@fas.harvard.edu), Alfonso Caramazza[1,2]; [1]Department of Psychology, Harvard University, [2]Center for Mind/Bran Sciences, University of Trento

Recognizing the identity of a face is computationally challenging – it requires performing subtle distinctions between different individual faces while achieving invariance across identity-irrelevant differences between images. Previous human fMRI studies have found information about individual faces with invariance across changes in viewpoint in the right anterior temporal lobe and in occipitotemporal cortex. It remains unclear, however, whether face representations in these regions differ in terms of their invariance across identity-irrelevant differences between images. To address this question, we investigated the invariance of representations of individual faces generalizing across different face parts. In a behavioral training session, participants were trained to recognize three individual faces. On the following day, they took part in an fMRI experiment in which they were asked to recognize the identity of those faces when seeing images of the whole face or images of half of the face (left, right, upper, lower). Information about face identity with invariance across changes in the face half was individuated only in the right anterior temporal lobe. This finding points to the right anterior temporal lobe as the most plausible candidate region for the representation of face identity.

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23.503 Exploring the functional organization of the superior temporal sulcus with a broad set of naturalistic stimuli

Ben Deen[1](bdeen@mit.edu), Nancy Kanwisher[1], Rebecca Saxe[1]; [1]Department of Brain and Cognitive Sciences and McGovern Institute for Brain Research, MIT

The superior temporal sulcus (STS) has been identified as a critical region for social perception. Prior experiments have used targeted contrasts (e.g., faces versus objects or human motion versus object motion) to investigate the functional organization of the STS. However, the space of visual social stimuli is very broad, and experiments intended to isolate a single feature may miss other dimensions of relevance to the STS. Additionally, while most prior work on the STS has focused on responses of individual voxels or regions of interest, recent fMRI studies in other domains have demonstrated that multivoxel patterns of activity often carry more information than mean responses alone. In the present study, we measured STS responses to 282 dynamic social stimuli (3s-long film clips depicting humans acting and interacting), and related responses and patterns to a number of continuous social dimensions. These dimensions included various types of biological motion (head, hand, eye, and leg motion), the presence of talking, presence of a social interaction, strength of emotions depicted, and emotional valence, with several low-level visual properties (luminance, contrast, and motion) included as controls. Patterns in a common posterior STS region explained unique variance in a number of social perceptual dimensions, including presence of biological motion, the presence of interactions and talking, and strength of emotions. Additionally, the presence of talking was predicted by patterns in multiple regions along the full length of the STS. Across the board, using patterns instead of mean responses improved sensitivity in predicting stimulus features. These results indicate that the pSTS plays a varied role in social perception, with response patterns in this region relating to a number of distinct stimulus dimensions.

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23.505 A single mechanism of temporal integration unites neural adaptation and norm-based coding

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What information is encoded in a cortical visual representation? That visual representations are distributed across the ventral temporal cortex is well established. fMRI adaptation studies demonstrate these neural codes are modulated by the perceptual similarity of sequential stimuli. Studies investigating prototype-based coding effects propose that neural responses are proportional to distinctiveness from a central reference, or prototype. In existing fMRI work, these two effects are considered independently. Here, we propose that these two effects arise as a consequence of a single mechanism of coding based upon temporal integration over recent stimulus history. Using a carry-over fMRI design, we show significant neural adaptation and prototype-based coding effects in a face-responsive region of interest in the right fusiform gyrus when effects are modeled discretely. By considering these effects as extremes of a single drifting norm model, we find that visual representations tend to encode identity in terms of intermediate stimulus history. Looking beyond the region of interest, we demonstrate that the effect of temporal context varies smoothly across the cortex, with the modulatory effect of recent visual history extending further back in time in a posterior to anterior fashion along the right ventral temporal cortex. These findings reframe two branches of the visual representation literature in terms of a unified encoding model. Importantly, this finding offers a perspective on the cortical topology of visual identity representations. We discuss these advances in terms of prior work related to the temporal qualities of visual stimuli.

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23.506 Using Functional Magnetic Resonance Imaging to Explore the Flashed Face Distortion Effect

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The Flashed Face Distortion (FFD) is a recently discovered illusion, that after a while of viewing, the faces become distorted and alien-like. The FFD is displayed by presenting a sequence of eye-aligned faces at a steady pace in the peripheral vision of the observer. This study uses fMRI to explore the changes in the human brain when perceiving different strengths of this illusion. Behaviorally, FFD strength was found to be influenced by the number of faces per sequence when the number was small. In this experiment, four levels of manipulations were conducted: 1) one fixed face changing only illumination, 2) two alternating faces, 3) a sequence of three faces cycling repeatedly, and 4) a sequence of non-repeated faces. The four conditions were presented in pseudo-randomized blocks, followed by a rating phase where participants subjectively rated the magnitude of the perceived distortion on a four-point scale. In addition to the main experiment, localizers were performed to identify face-selective areas including the FFA, OFA, and STS in the right hemisphere, and retinotopic mapping allowed demarcation of visual areas V1~V4, which were later overlapped with FFD task-driven activation. Within these ROIs, the BOLD signals were compared across the four FFD conditions and correlated with subjects' FFD ratings. Multiple regression analysis, including the rating of FFD strength and a dummy variable for subject, revealed significant regression of perceived FFD strength on the PSC in these ROIs. This regression also entered whole-brain voxelwise analysis, which additionally revealed non-visual areas, including the precuneus, posterior cingulate, bilateral insular cortices, and inferior parietal lobules (IPL) negatively correlate with perceptual FFD strength. Taken together, these results suggest that the brain network consisting of the early visual cortex, higher level face-selective areas, as well as fronto-parietal areas are involved in modulating the FFD illusion.

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23.507 Probing the representation of face and object orientation in human ventral visual cortex

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Freiwald and Tsao (2010) observed a qualitative difference along the macaque ventral stream regarding neural tuning functions to face orientation (rotation in-depth). Posterior patches (middle-face patches) exhibited responses maximally tuned to single preferred views, antero-lateral patches exhibited bimodal tuning functions to mirror-symmetric views, and a maximally anterior face-patch encoded face identity regardless of orientation. These findings provide important clues concerning how primates achieve invariant face and object recognition. Recently, experiments combining fMRI and multivariate pattern analysis (MVPA) found face orientation information in the human ventral stream, and some claimed evidence of mirror-symmetric encoding in ventral areas including LO and FFA (Axelrod and Yovel, 2012; Kietzmann et al., 2012). However, a critical issue requiring special attention is the interpretation of MVPA results. In particular, if diagnostic information regarding a dimension of interest is detected, in this case, regarding face orientation, the question arises concerning how that information is encoded in the measured signals, and the relationship between such signals and underlying neural populations. Here, we present a model-driven data-analytic approach that, under neural clustering assumptions shown to occur in non-human primates (Wang et al., 1996, Sato et al., 2013), provide a tool to measure mirror-symmetric tuning of the neural populations presumably sampled by fMRI voxels. Given a small number of biologically plausible parameters, we simulate the expectancy of a family of model similarity matrices associated with a set of experimental conditions, each defined by a concrete model parameter combination. Model parameters include the tuning width of assumed neural populations, their degree of mirror-symmetry, and the strength of the representation of various views covering a full rotation of the head. Our data (Ramirez et al, 2010), when scrutinized with this method, do not support mirror-symmetric tuning to face orientation in FFA. Instead they are compatible with a monotonic code reflecting angular disparity.

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23.508 Face configuration processing in monkey cortex

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We performed two monkey fMRI experiments to identify cortical regions involved in face configuration processing. In experiment 1, real and schematic faces (replaced face features with gray ovals) with veridical and scrambled configurations were created by manipulating face configurations and features orthogonally. Mosaic-scrambled versions of all faces were used to control for low-level differences across conditions. In experiment 2, veridical and scrambled faces were created by disassembling a composite image (four veridical faces positioned around a fixation point) in two ways. We either presented each full set of face features from one of the four veridical

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faces separately, or spread them over the four faces (hence showing four different features from the four different faces). This resulted in scrambled faces that fully controls for local low-level stimulus differences compared to the veridical faces while destroying the veridical configurations. To further control for different degrees of stimulus spreading and asymmetry, we created two other conditions with face features arranged in a scrambled configuration at each of the four positions in the initial composite images. Finally, two additional control conditions were created with objects. Three monkeys were scanned (3T, contrast-enhanced, 1.25 mm isotropic) while performing a fixation task. Results of both experiments revealed a significant face configuration effect in four face patches: bilateral ML and MF, left AD and a prefrontal patch rPLf. Although a significant 3-way interaction (configuration x face type x mosaic-scrambling) was found in MF, lAD and rPLf, only lAD and rPLf showed a face configuration effect with the real, but not schematic faces (Exp. 1). Furthermore, only ML and MF, but not lAD and rPLf showed a significant face feature effect (Exp. 2). These suggest a unique role of lAD and rPLf in processing intact veridical face configurations, but not schematic face-like configurations and face features in monkeys.

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23.509 **Expectations of faces and words differentially activate the primary visual cortex** Jiangang Liu[1](liujg@bjtu.edu.cn), Xin Jiang[1], Pu Zheng[2], Kang Lee[2]; [1]School of Computer and Information Technology, Beijing Jiaotong University, Beijing, 100044, China., [2]Dr. Eric Jackman Institute of Child Study, University of Toronto, Toronto, Ontario, Canada

It has been well established that top-down influence plays an important role in processing of objects with which we have high level of expertise. One example is that expectation of visual input of faces or words facilitates the detection of the exemplars from these categories. Recent fMRI studies revealed that responses of some category-specific regions in the ventral occipitotemporal cortex (VOT) can be enhanced by top-down expectations without the presence of real stimuli. However, it is unclear whether such top-down expectations also activate the primary visual cortex differentially. Here we manipulated the participants' expectation of object categories (i.e., faces versus words) to address this question. We had two within-subject tasks: the face task and the word task. Each task included a training period and a testing period. For the face task, the training period included increasingly noisy faces and the test period included pure-noise images. For the word task, the training period included increasingly noisy words and the test period included the same pure-noise images as in the face task. Participants were misled that in the testing period 50% of the pure-noise images contained faces or words respectively, and they must detect them. We trained support vector machines (SVM) on the fMRI data scanned during the training periods of the face and word tasks and then tested the learned models with the fMRI data from the testing periods. We found that the discriminant accuracy was 76.57% for V1, 89.64% for V2, and 89.92% for V3~V5. In addition, in the face- and words-preferential areas of VOT (i.e., FFA and VWFA), the accuracy was 61.36%. Our findings suggest that top-down expectations of faces or words can activate the primary visual cortex with even greater differentiation than the face- or word-preferential areas in the VOT.

23.510 **Consecutive TMS–fMRI: Remote effects of OFA disruption on the face perception network** Lily M. Solomon-Harris[1](lilysh@yorku.ca), Jennifer K.E. Steeves[1]; [1]Department of Psychology and Centre for Vision Research, York University, Toronto, Canada

The face perception system is comprised of a network of connected regions including the middle fusiform gyrus ("fusiform face area" or FFA), the inferior occipital gyrus ("occipital face area" or OFA), and the posterior part of the superior temporal sulcus. These regions are typically active bilaterally but may show right hemisphere dominance. The functional magnetic resonance imaging (fMRI) response of the right FFA is normally attenuated for face stimuli of the same compared to different identities, called fMR adaptation. Patients with prosopagnosia who are unable to visually recognize faces and who show right OFA damage, nonetheless show face-selective activation at the right FFA (Rossion et al., 2003; Steeves et al., 2006). However, the sensitivity to face identity is abnormal in the right FFA and does not show the typical release from adaptation for different face identities (Steeves et al., 2009). This indicates that in these patients, the FFA is not differentiating face identity and suggests that an intact right OFA is integral for face identity coding. We used offline repetitive transcranial magnetic stimulation (TMS) to temporarily disrupt processing in the right OFA in healthy controls. We then immediately performed fMRI to observe changes in BOLD signal across the face network using a face adaptation paradigm. We found that release from adaptation persisted despite right OFA disruption. Furthermore, we observed increased activity in remote face-selective regions. These results demonstrate remote effects of TMS in the face perception network where TMS disruption at the target site may permit connected regions in the network to utilize more of the available processing power. Unlike patients with OFA damage, TMS disruption of the OFA in one hemisphere appears to leave FFA response properties intact.

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23.511 **The Occipital Face Area is Causally Involved in Viewpoint Symmetry Judgments of Faces** Tim C Kietzmann[1,2](tkietzma@uos.de), Sam Ling[3], Sonia Poltoratski[2], Peter König[1,4], Randolph Blake[2,5], Frank Tong[2]; [1]Institute of Cognitive Science, University of Osnabrück, [2]Vanderbilt Vision Research Center, Psychology Department, Vanderbilt University, [3]Boston University, [4]Department of Neurophysiology and Pathophysiology, University Medical Center Hamburg Eppendorf, [5]Department of Brain and Cognitive Sciences, Seoul National University

Humans are highly proficient at recognizing individual faces from a wide variety of viewpoints, but the neural substrates underlying this ability remain unclear. Recent work suggests that viewpoint-symmetric responses to rotated faces, found across a large network of visual areas, may constitute a key computational step in achieving full viewpoint invariance. Here, we used transcranial magnetic stimulation (TMS) to examine whether the occipital face area (OFA) causally contributes to the perception of viewpoint symmetry. The experiment followed a 2x2 design with TMS (repetitive vs. sham) and task (symmetry vs. angle judgments) as experimental factors. Subjects underwent 5 minutes of either sham stimulation or true 1Hz rTMS to the right OFA prior to each 4-minute block of behavioral test trials. Visual stimuli were presented ipsilateral to the site of TMS stimulation to avoid retinotopically specific impairments. Subjects reported either which of two consecutively presented pairs of face viewpoints was mirror-symmetric (symmetry task) or which pair of faces had a larger angular difference (angle task). Prior to the experiment, both tasks were titrated by an adaptive staircase procedure (QUEST) to achieve an average of 80% correct performance. Compared to sham, rTMS led to a significant decrease in performance specifically for viewpoint symmetry judgments, whereas no significant differences were found for the angle task. A repeated-measures ANOVA revealed a significant interaction effect, indicating that the effect of rTMS over OFA was larger for symmetry than for angle judgments. Our data provide novel evidence for the causal involvement of OFA in the processing of viewpoint symmetry and provide important restrictions on models of viewpoint symmetry and face perception in general. In particular, the specific effect on viewpoint symmetry judgments after rTMS applied to the ipsilateral OFA provides support for proposals emphasizing the role of inter-hemispheric sharing of information in the perception of viewpoint symmetry.

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23.512 **What is a face?** Talia Brandman[1,2](talli.brandman@gmail.com), Galit Yovel[1,2]; [1]Sagol School of Neuroscience, [2]School of Psychological Sciences

What is a face? According to the dictionary a face is the front part of the head that includes the eyes, nose and mouth. To what extent this definition is consistent with the way our mind defines a face? The highly-selective cognitive and neural responses generated for faces, allow us to re-evaluate this definition by applying an inductive reasoning approach. In particular, if a stimulus is visually perceived as a face and exclusively activates face-selective neural and cognitive mechanisms, then our mind considers it a face. Recent evidence suggests that based on this approach, faceless heads in body context, which do not include internal facial features should be considered faces as they generate the most established face-specific markers. This includes face detection, inversion effect, configural processing, and face-selective neural responses. In particular, faceless heads in body context were perceived as faces during a brief masked face detection task. Second, they generate a face-sized inversion effect, which is specifically associated with face-selective brain areas. Third, face-selective areas show face-like configural processing of faceless heads in body context. These effects are not found for headless body stimuli or bodies presented from the back ruling out the possibility that face-selective markers are tuned to person-related stimuli rather than faces. These findings suggest that our definition of what the brain categorizes as a face should be modified to include also stimuli without internal facial features, thereby impacting both experimental and computational approaches to face perception. Generally, we show how empirical findings may go beyond our deductively defined concepts to expand our understanding of human cognition.

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23.513 Face animacy does not impact the N170 inversion effect

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Face orientation is known to affect visual processing such that inversion typically impairs recognition ability (Yin, 1969). While the electrophysiological component known as the N170 is generally greater for faces versus non-face stimuli (Bentin, Allison, Puce, Perez, & McCarthy, 1996), inverted faces typically exhibit higher amplitudes compared to upright faces (Anaki, Zion-Golumbic, & Bentin, 2007). Presently, we investigated the generality of this neural inversion effect by comparing the inversion effect for real and artificial faces. Artificial faces are a theoretically important example of an "other" face category and recent results indicate that face animacy impacts early visual ERPs (Balas & Koldewyn, 2013). Participants (N=15) viewed 8 real and 8 artificial faces that were presented upright and inverted in a pseudo-random order for a total of 160 experimental trials. Event-related potentials (ERPs) were recorded with a 64-channel net while participants completed an oddball detection task. We analyzed the mean amplitude and the latency of the P100 and the N170 components using a 2 x 2 x 2 repeated-measures ANOVA with animacy (real or doll), orientation (upright or inverted), and hemisphere (right or left) as within-subject factors. This revealed a main effect of orientation on the mean amplitude of the P100 (p = .004), and the N170, (p <.001), with inverted faces eliciting larger amplitudes. In addition, we observed a main effect of orientation on the latency of the P100 (p = .009). Our findings indicate that inverted faces, whether real or artificial, bilaterally enhance the P100 and N170 and delay the P100. Face animacy thus does not appear to impact the inversion effect on early visual ERPs, suggesting that real and artificial faces are potentially coded for by either a shared neural population, or at least by populations with similar tuning characteristics.

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23.514 Influence of autistic-like and empathetic traits on early ERPs to emotional faces

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Personality traits such as social skills have been shown to modulate early neural responses to emotional faces during expression-irrelevant tasks. We explored whether autistic-like traits and empathy modulated the time course of emotional face processing, and whether this depended on the facial feature fixated and on the task. ERPs were recorded in response to presentations of fearful, joyful or neutral faces while fixation was restricted to the left eye, right eye, nose or mouth using an eye-tracker. In the gender discrimination task, higher Autism Quotient (AQ) scores were associated with a decrease in the face-sensitive N170 component regardless of emotions and fixation locations, possibly reflecting different levels of structural encoding when the task is emotion-irrelevant. In the explicit emotion discrimination task, higher AQ scores were associated with an increased P1 component for specific locations and emotions, reflecting complex modulations of attention to emotional stimuli. High scores on the Empathy Quotient (EQ) were associated with a decrease in the N170 only in the explicit task, possibly reflecting different levels of structural encoding when the task is emotion-relevant. Results suggest that individual differences in autistic-like traits and empathy influence attention to and structural encoding of emotional faces differently as a function of task instructions.

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23.515 Frequency coding of facial parts

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How the brain samples spatiotemporal signals in order to form an accurate representation of its environment has been a long-standing issue in cognitive neuroscience. One hypothesis that has gained interest over the years is that the brain samples visual information through periodic and transient processes (see Tallon-Baudry & Bertrand, 1999; VanRullen & Koch, 2003; VanRullen & Dubois, 2011). Although traces of oscillatory processes have been repeatedly found in psychophysical experiments since the middle of the last century, efforts to map their frequency to specific aspects of visual processing remain elusive. Here, we attempted at filling this gap. One hundred and twelve participants did 900 trials of a face gender categorization task in which the achromatic and isoluminant chromatic content of faces were sampled in space and time with 3D gaussian apertures, i.e. Bubbles (see Gosselin & Schyns, 2001). This reverse correlation technique first allowed us to find that the achromatic information in the eyes, and the isoluminant chromatic information in the mouth and right eye regions were the most useful for this task. Next, time-frequency wavelet transforms were performed on the time series recorded in these anatomical facial regions to assess the frequency and latency at which they were sampled. The results showed that achromatic and isoluminant chromatic information within the same facial part were sampled at the same frequency (but at different latencies), whereas different facial parts were sampled at distinct frequencies (ranging from 6 to 10 Hz). This encoding pattern is consistent with recent electrophysiological evidence suggesting that facial features are 'multiplexed' by the frequency of transient synchronized oscillations in the brain (see Schyns, Thut & Gross, 2011; Smith, Gosselin & Schyns, 2005, 2006, 2007; Thut et al., 2011; Romei, Driver, Schyns & Thut, 2011).

23.516 The N170 is driven by the presence of horizontal facial structure

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Horizontal contours convey vital information for identifying faces (Dakin & Watt, JoV 2009), and orientation selectivity—i.e., relative sensitivity to information conveyed by horizontal and vertical contours—correlates with face identification accuracy (Pachai et al., Front Psych 2013). The face inversion effect (FIE), a decrease in identification accuracy after stimulus inversion, is observed when horizontal, but not vertical, contours are retained (Hashemi et al., VSS 2012). Indirect evidence suggests that the N170 component of the ERP may have similar orientation selectivity: the N170 is affected by face inversion (Jacques & Rossion, NeuroImage 2007; Rousselet et al. JoV 2008), and the N170 FIE also is sensitive to horizontal contours (Jacques et al., VSS 2011). Here, we directly tested the effect of orientation filtering on the N170 for upright face processing. We measured identification accuracy in a 6-AFC task with filtered test faces. Test stimuli were generated using a ±45 deg orientation filter centered on either the horizontal (HORZ) or vertical (VERT) orientation. Increasing the bandwidth of the filter by ±9 deg steps formed eight additional filtered conditions, and an unfiltered face was used in another condition. In both the HORZ and VERT conditions, response accuracy increased linearly with filter bandwidth. However, the effect of bandwidth was eight times larger in the VERT condition. This result is consistent with previous reports: adding horizontal contours to a vertical base improved identification, but adding vertical contours to a horizontal base had a much smaller effect. Critically, we observed similar linear effects of filter bandwidth on N170 amplitude and latency: increasing filter bandwidth reduced latency and increased amplitude, and the effect was significantly greater in the VERT condition. Finally, behavioural and N170 amplitude orientation tuning were correlated (r=0.72 left, 0.58 right). We conclude that horizontal contours may largely drive the neural response to intact faces.

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23.517 Effects of inversion and contrast-reversal on objective face detection thresholds revealed by sweep steady-state visual evoked potentials

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Human observers are able to rapidly notice the presence of a face in a natural scene. In order to better quantify the threshold of face detection, we have conducted a study using the sweep steady-state visual evoked potentials (SSVEP) method in EEG (Ales et al., 2012, JOV, 12, 1–18). More precisely, we parametrically varied the visibility of a face stimulus with phase-scrambling while alternating it at a fixed rate with noise stimuli (3 Hz alternation or 6 images/second). While the face gradually emerged from noise over the course of a trial sequence, EEG responses at 3 Hz increased abruptly at 30%-35% phase coherence over the right occipito-temporal region, providing an objective face detection threshold in the human brain. The purpose of the current study is to test the degree to which this response is specific to face structure rather than reflecting general shape perception. We recorded 128-channel EEG in 13 observers presented with sweep sequences containing faces that varied in orientation (upright vs. inverted) and contrast polarity (positive vs. negative). Picture-plane and contrast inversion are well-known manipulations to which faces are particularly sensitive, in contrast to other object categories. Robust responses emerged specifically at 3 Hz on occipito-temporal electrodes at 30%-35% phase coherence for upright faces, replicating our previous experiment. However, these responses were delayed (≈40-45% coherence) and reduced (60%-75% of the reponse) both for inverted and negative polarity faces. These findings indicate that periodic alternations between intact and scrambled faces generate frequency-locked responses that are partly selective to face structure, so that it can be used as an objective index of face detection. The sweep SSVEP method is a promising tool for measuring high-level visual perception thresholds rapidly and objectively in a variety of populations, including infants and patients.

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23.518 **Dissociation of Part-Based and Whole-Based Neurophysiological Responses to Faces by Means of EEG Frequency-Tagging** Bruno Rossion[1](bruno.rossion@psp.ucl.ac.be), Anthony Norcia[2], Adriano Boremanse[1]; [1]Institute of Research in Psychology and Neuroscience, University of Louvain, [2]Department of Psychology, Stanford University

The goal of this study was to isolate repetition suppression effects for each part of a whole face stimulus. To do so, the left and right halves of face stimuli were flickered at different frequency rates (5.88 Hz or 7.14 Hz) while changing face identity or not at every stimulation cycle (Figure 1). Recording high-density electroencephalogram (EEG) in 11 human participants fixating in the centre of the face, robust responses were observed to each face half at these specific frequency rates. These part-based EEG responses were larger in amplitude when different as compared to repeated face half identities were presented at every stimulation cycle. Contrary to whole-face repetition suppression effects, which are usually found over the right occipito-temporal cortex (Rossion & Bormemanse, J Vis. 2011 Feb 23;11(2)), these part-based repetition suppression effects effects were found over all posterior electrode sites. Most importantly, they did not decrease when the two face halves were manipulated by separation, lateral misalignment, or inversion (Figure 2). Critically, there were also robust intermodulation (IM) components in the EEG spectrum (e.g., 7.14 – 5.88 = 1.26 Hz), which are unequivocally produced by neuronal populations that interact or integrate the two face parts nonlinearly. These IM components were found mainly over the right occipito-temporal cortex and were significantly reduced following the aforementioned manipulations. Additionally, the IM components decreased substantially for face halves belonging to different identities (Figure 3), which form a less coherent face than when they belong to the same face identity. These observations provide objective evidence for dissociation between part-based and whole-based responses to faces in the human brain, suggesting that only whole-based responses may reflect high-level, possibly face-specific, visual representations.

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23.519 **Integrative processing of age, gender and ethnicity of faces: an ERP study** Esther Alonso-Prieto[1, 2](eapvan@gmail.com), Jason J S Barton[1, 2]; [1]Department of Medicine (Neurology), Department of Ophthalmology and Visual Sciences, [2]Department of Ophthalmology and Visual Sciences

Background: Age, gender and ethnicity are all properties that can be deduced from a face, and all are also relevant to the processing of the identity of the face. Whether these use shared neural resources is not certain. Objective: We aimed to determine if the processing of one of these three dimensions influenced the processing of the others, on electrophysiological recordings. Methods: 13 observers with >3 years of experience with Asian and Caucasian faces made binary discriminative decisions of facial gender (male/female), age (young/old) or ethnicity (Asian/Caucasian) in separate blocks. Each block contained baseline trials in which only the relevant dimension varied and 'interference' trials in which both the relevant and one irrelevant dimension varied. Baselines vs. interference conditions were compared for each block separately in an analysis of N170 peak amplitude for right and left hemisphere electrodes. Results: Behavioral performance was equivalent for the three dimensions. The N170 was the most robust component being highest at P8 and PO8 electrodes. In Age discrimination blocks, trials with interference from ethnicity showed larger N170 amplitudes in the right hemisphere. There was no difference between the baseline and trials with interference from gender. In Ethnicity discrimination block, there was an opposite effect from interference from age, with smaller N170 amplitudes instead, and now only in the left hemisphere. Again, there was no difference in trials with interference from gender. In Gender discrimination blocks, trials with interference from age or ethnicity did not differ from the baseline trials. Conclusions: Age and ethnicity are processed in an interactive fashion, but gender perception appears to be independent, neither influencing processes while the other dimensions are being discriminated, nor being influenced by these other dimensions when subjects are discriminating gender.

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23.520 **The time-course of face-selective ERP activation during ultra-rapid saccades** Jacob Martin[1,2](jacobgmartin@gmail.com), Max Riesenhuber[2], Simon Thorpe[1]; [1]Centre de Recherche Cerveau & Cognition, CNRS-Université Toulouse 3, Toulouse, France, [2]Lab for Computational Cognitive Neuroscience, Georgetown Univ Med Ctr, Washington DC, USA

Humans can initiate ultrafast saccades towards faces as early as 100ms post-stimulus onset (Crouzet & Thorpe, 2010, J Vis), and even the mean saccadic reaction time can be as short as 120-130 ms, imposing very serious temporal constraints on the underlying mechanisms. To try and understand which brain structures are involved in triggering these very short latency responses, we explored the neural sources of these saccades by simultaneously recording ocular movements and electroencephalography under a variety of conditions. For example, subjects were required to make fast and accurate saccades to gray-scale face images that were pasted into complex and varied background scenes with random positions and sizes. We sought to determine the earliest activity which could predict the location of a visual face target. Single trial EEG classification results indicate that EEG potentials recorded over occipital locations reliably predicted the location of the face as early as 50ms post-stimulus onset. These results suggest the intriguing hypothesis that there may be face-selective neural representations in early visual areas.

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3D Perception: Space

Saturday, May 17, 8:30 am - 12:30 pm
Poster Session, Pavilion

23.521 **Outer-edge Disparity Determines The Depth of Panum's Limiting Case and Classical Stereopsis** Huayun Li[1 2](1031208135@qq.com), Laipeng Jing[1 2], Ruoyun Xu[2], Dongchuan Yu[1 2]; [1]Key Laboratory of Child Development and Learning Science, Southeast University, [2]Research Center for Learning Science, Southeast University

Panum's limiting case often refers to the perceived configuration difference that occurs between two features presented to one eye combined with only one feature presented on the other eye. Classical stereopsis often describes the configuration that the number of features presented to both eyes is the same. In previous reports, the outer-edge disparity is only considered in gap stereopsis but not in other configurations, and Panum's limiting case is not classified under classical stereopsis. Therefore, we attempted to investigate the depth of Panum's limiting case and classical stereopsis using configurations transitioning from the former case to the latter. Some of the configurations have the same outer-edge disparity while others have different disparities. Participants were asked to report whether the depth of any two configurations are identical. The results show that although there are various transforming stimuli, the depth of Panum's limiting case and classical stereopsis is the same when the outer-edge disparity is equal. Otherwise, the depth is different. The results also indicate that when the disparity exceeds the disparity fusion range (more than 16'), most participants fail to perceive the depth of stereopsis. This indicates that the depth of Panum's limiting case and classical stereopsis is determined by the outer-edge disparity and constrained by the disparity theory. Keywords: Panum's limiting case; Classical stereopsis; outer-edge disparity.

23.522 **Background Texture Nonlinearly Modulates Distance Effect on Perceived Size** Chia-Ching Wu[1](ccwu86@ntu.edu.tw), Chien-Chung Chen[2]; [1]Department of Psychology, Fo Guang University, [2]Department of Psychology, National Taiwan University

The perceived size of an object depends not only on the size of the projected image on the retina but also the perceived distance of the object (size-distance invariance hypothesis). Here we investigated how background texture modulates this perceived size-distances relationship. The target was a disk with 136.8 arcmin diameter on a frontoparallel plane. The background was either blank or with texture filled with small, medium or large disk elements whose diameter was 68.4, 136.8 and 273.6 arcmin respectively. The perceived distance of the display was determined by binocular disparity of -13.4, -7.9, 0, 7.9, and 13.4 arcmin. We used a two interval forced choice paradigm to measure perceived target size at various combinations of disparity and background texture size. In each trial, the target with a background and a particular disparity was presented in one interval while a reference disk on a blank background and zero disparity was presented in another interval. The task of the observer was to determine which interval contained a larger disk. We measured the point of subjective equality (PSE) for the perceived target size with a staircase procedure. With blank background, the perceived target size increased with disparity with a slope 0.35. The presence of a background texture reduced the slope to 0.16-0.24 across background size. The large background texture shifted the perceived size-distance function downward while the small background texture shifted it upward. Hence, while there was a linear relationship between perceived target size and distance and between target size and background texture size, the presence of texture altered the relationship between perceived target size and distance. Such result cannot be explained by the maximum likelihood theory of cue combination but a nonlinear interaction between background size and distance.

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23.523 Miscalibration of depth cues in the developing visual system

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Perception of depth from both monocular and binocular cues develops in the first year of life. However, reduction of discrimination thresholds via weighted averaging of depth cues does not develop until much later in childhood (Nardini, Bedford & Mareschal, PNAS 2010). Cue combination models often assume that cues are well calibrated (unbiased). In that case the optimal strategy is to take a reliability-weighted average. If, however, depth cues are not well calibrated in young observers, then averaging them may not be the optimal strategy. To investigate this possibility we measured the integration, weighting, and calibration of two depth cues in adults (N=3) and 5- to 8-year-olds (N=20). Observers judged which plane, a 45° standard or a variable comparison, was more slanted. Slant was defined by a texture gradient, a binocular disparity gradient, or both together. We measured (1) slant discrimination thresholds when given single vs combined cues, (2) the relative weighting for texture vs disparity, measured by comparing consistent with ±5° conflicting planes, and (3) the relative bias in slant perceived via texture vs disparity, measured by comparing texture-only with disparity-only planes. Adults reduced their discrimination thresholds when given combined cues vs the best single cue, and gave more weight to the more reliable cue; children did not reduce their discrimination thresholds or give more weight to the more reliable cue. While adults showed small (median 3°) biases between cues, children showed much larger biases: median 14°, including biases greater than 22.5° in 1/3 of observers. These results indicate that in mid-childhood, the visual system is still learning to calibrate depth cues against each other. This raises the possibility that the developing visual system does not combine depth cues because of calibration issues, in line with ideal observer strategies for dealing with biased cues (Ernst & di Luca, 2012).

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23.524 Shape aftereffects reflect shape constancy operations: Appearance matters

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One of the earliest reported visual aftereffects is the shape aftereffect, in which looking at a particular shape can make subsequent shapes seem distorted in the "opposite" direction. After viewing a narrow ellipse, for example, a perfect circle can look like a broad ellipse. It is generally thought that shape aftereffects are determined by the retinal dimensions of successive shapes. However, perceived shape is invariant for the large changes in retinal image resulting from different viewing angles, raising the previously untested question of whether shape aftereffects are determined by the dimensions of retinal shapes or perceived shapes. By viewing adaptors from an angle, with subsequent fronto-parallel tests, we establish that shape aftereffects are not solely determined by the dimensions of successive retinal images. Moreover, by comparing adaptation to the same retinal shape with and without stereo surface-slant cues, we show that shape aftereffects reflect a weighted function of retinal image shape and surface slant information, a hallmark of shape constancy operations. Our data establish that shape aftereffects are influenced perceived shape, as determined by constancy operations, and therefore likely involve higher-level neural substrates than previously thought.

23.525 Correct blur and accommodation information is a reliable cue to depth ordering.

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Marshall et al. (1996) showed that blur could in principle also be used to determine depth ordering of two surfaces across an occlusion boundary from the correlation between the boundary's blur and the blur of the two surfaces. They tested this experimentally by presenting stimuli on a conventional display and manipulating rendered blur. This approximates the retinal image formed by surfaces at different depths and an occlusion boundary, but only when the viewer accommodates to the display screen. Accommodation to other distances creates incorrect blur. Viewers' judgments of depth ordering were inconsistent: they generally judged the sharper surface as nearer than the blurrier one regardless of boundary blur. We asked if more consistent performance occurs when accommodation has the appropriate effect on the retinal image. We used a volumetric display to present nearly correct focus cues. Images were displayed on four image planes at focal distances from 1.4-3.2 diopters. Viewers indicated the nearer of two textured surfaces separated by a sinusoidal boundary. The stimuli were presented either on one plane as in previous experiments or on two planes (separated either by 0.6 or by 1.2 diopters) such that focus cues are nearly correct. Viewers first fixated and accommodated to a cross on one of the planes. The stimulus was then presented either for 200ms, too short for accommodative change, or for 4s, allowing accommodative change. Responses were much more accurate in the two-plane condition than in the single-plane condition, which shows that appropriate blur can be used to determine depth ordering across an occlusion boundary. Responses were also more accurate with the longer presentations, which shows that accommodation aids depth-order determination. Thus, correct blur and accommodation information across an occlusion boundary yields more accurate depth-ordering judgments than indicated by previous work.

23.526 Are blur and disparity complementary cues to depth?

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It has been claimed that disparity and blur are complementary cues to depth [Mather and Smith, 2000]. In particular, one study [Held et al 2012] has shown that depth discrimination from disparity is better near the fixation plane but depth discrimination from blur is better far beyond beyond the fixation plane. We carried out an experiment similar to Held et al, but we used shutter glasses for the stereo display rather than a volumetric display. Our stimuli consisted of pairs of dead leaves texture patterns which were visible through windows in the fixation plane. Viewing distance was 28 cm, rendered disparities were up to a few degrees, and presentation time was 250 ms. For each trial, subjects had to judge which of two texture patterns was farther in depth. Conditions included disparity+blur and disparity only (binocular) and blur only (monocular). The underlying assumption of the Held et al experiment is that increasing the disparity and/or blur causes a surface to be seen as farther away. We found, however, that this assumption failed for the majority of our subjects. The failure for disparity is not surprising since it has been shown that increasing disparity into the diplopic range can lead to a reduction in perceived depth [Richards and Kaye, 1974]. The failure for blur seems to be due to a tendency for subjects to perceive the more blurred stimulus as closer rather than further - despite the presence of the sharp window frame which is a cue that the blurred surface is beyond the window [Mather and Smith, 2002]. We conclude that if blur and disparity cues are combined to improve quantitative depth perception, then the rules of combination are more complicated than has been proposed up to now.

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23.527 Modulation of distance estimation of visual object by stimulation of vergence and accommodation

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The apparent distance can be modulated by vergence alone. The same is true of accommodation. There is conflicting evidence about the effect under the condition in which both of them are varied independently. Here we investigated the role of vergence and accommodation on the absolute distance perception. A stereoscope, 60 cm viewing distance, was used to present dichoptic stimuli. A white square with a black cross-shaped fixation was presented in dark surroundings. The offset between the right eye image and the left eye image was manipulated to vary vergence. A pair of concave or convex lenses was set in front of the eyes to vary accommodation. The size of the image on each monitor was controlled to eliminate the change of image size on the retina caused by the lens. Prior to the experiment, three subjects were trained to give verbal estimates of the distance of a single visual object at different distance. They had normal or corrected to normal vision and normal stereovision. They were in their 20s. In the experiment, the stimulus had an offset to yield vergence of 8.2, 7.2, 6.2, 5.2, or 4.2 degree, and the subject observed through a pair of lenses with -1.75, -1.25, 0, 1.25, or 1.75 diopter. Every offset-lens combination was tested in a random order. Subjects were asked to fixate the center of the target and give the apparent distance verbally. They could spend as much time observing as they wanted. Our results indicated that the offset between the images modulated the perceived distance in agreement with the theoretical value. For lenses, the modulation was about one-tenth of the theoretical value. A similar experiment was conducted with blurred images. The results were similar to that with sharp images.

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23.528 **Judgments of egocentric distance within indoor and outdoor environments: Context matters with restricted and unrestricted fields of view.** Daniel A. Gajewski[1](gajewsk1@gwu.edu), Sandra Mihelič[1], Courtney P. Wallin[1], John W. Philbeck[1]; [1]Department of Psychology, The George Washington University

Egocentric distance judgments are impaired when the field of view is limited. A prominent account suggests that the impairment derives from an inadequate representation of the geographical slant of the ground surface, which depends on the sequential integration of ground cues. In support of this view, near-to-far scanning with a restricted view has been shown beneficial in an outdoor experimental setting. In contrast, performance in an indoor setting has shown that occluding the nearby ground plane results in smaller deficits than occluding the greater room space. The present study aimed to reconcile these outcomes by matching the designs and manipulations used in indoor and outdoor settings. We report three experiments that compare blind walking performance with a restricted view (≈15° square aperture) to that with an unrestricted view of the target and scene context. Restricted viewing conditions were near-to-far scanning, far-to-near scanning, and/or with head held steady. In Experiment 1 (indoors), errors were greater with the restricted view (-25%) than with an unrestricted view (-15%) regardless of viewing condition (steady or near-to-far scanning) and regardless of block order. In Experiment 2 (outdoors), which employed a completely randomized design, target distances were actually overestimated with the restricted view (+8%) and nearly unbiased with an unobstructed view (-2%) regardless of viewing condition (near-to-far or far-to-near scanning). In Experiment 3 (outdoors), there were no reliable differences between viewing conditions (restricted steady vs. unrestricted view) regardless of block order. The pattern of results indicates strikingly different biases in two different but similarly reduced-cue contexts. Further, the observed bias even with an unrestricted view differed between indoor and outdoor contexts. Aspects of these data are not predicted by previous work and suggest the need for a contextual-scaling framework. A breakdown of context effects and an analysis of potential sources for these will be discussed.

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23.529 **Both own and other object shadows compress perceived distance** Christopher Kuylen[1,2](Christopher.Kuylen@gmail.com), Benjamin Balas[1,2], Laura Thomas[1,2]; [1]Department of Psychology, North Dakota State University, [2]Center for Visual and Cognitive Neuroscience, North Dakota State University

People represent their shadows as an extension of the physical body, perceiving a target object as significantly closer to them when they cast a shadow toward this object (Kuylen, Balas, & Thomas, in press). We investigated whether people represent all shadows as extensions of the objects to which they belong. Are the cast-shadows of inanimate objects also capable of perceptually altering space by acting as an extension of the object they represent? Participants (N=60) viewed a target object and estimated the distance between themselves and this object with a perceptual matching paradigm (Witt, 2011) in one of three experimental conditions: (1) while a light projected their cast-body shadow toward the target, (2) while a light projected the cast-shadow of the target toward participants, (3) and under a control condition. Participants estimated the target to be significantly closer to them either when they cast a shadow toward this object or when the object cast a shadow toward them than in the control condition ($p < .001$ in each case), but the two lighting conditions did not differ from each other ($p = .250$). These results demonstrate that shadows act as an extension of the item to which they belong, making objects in the environment that cast a shadow appear closer to observers than they actually are. The results add new support to the hypothesis that people represent all shadows as belonging to the object from which they are cast. Even though shadows are purely visual stimuli that can never impact the physical environment, they nonetheless impact how people perceive the physical reality of the world around them.

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23.530 **Large systematic biases in pointing to real and virtual unseen targets.** Jenny Vuong[1](j.vuong@pgr.reading.ac.uk), Lyndsey C. Pickup[2], Andrew Glennerster[1]; [1]University of Reading, School of Psychology and Clinical Language Sciences, [2]Mirada Medical, Oxford

People can keep track of the visual direction of objects in their environment as they move, despite those objects being out of view. However, there are no detailed models to suggest how this may be done. Generating a 3D model and keeping track of the observer's location in that model is a possibility, but this would predict either no errors or a consistent pattern of errors dependent on the accuracy of the 3D model. 20 observers viewed four coloured boxes arranged in two visual directions in a real room with maze-like walls, and viewed the same box layouts in a virtual replica. Observers viewed the boxes as long as they needed, then walked to one of three pointing zones from where, using a tracked hand-held device they would 'shoot' 32 times in a random order at the four boxes. The boxes were not visible at any time after the participant left the viewing zone. In some conditions, participants took a short cut to the shooting zones. We found that pointing errors in this task varied over a wide range (mean bias, averaged over 72 trials and 20 observers per condition, varied by at least +/- 30 deg) but these biases were not random. They were highly correlated in the real and virtual conditions, although biases were larger in the virtual condition. In the maze and the direct walking conditions, biases were also highly correlated despite large differences for different pointing zones. Data from an experiment in which pointing zones were located on two different sides of the target boxes ruled out a model based on a consistent mislocalisation of the target boxes. Instead, the data suggest a systematic error in computation of pointing direction such as a compression in the gain of the rate of updating visual direction.

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23.531 **Direct manipulation of perceived angular declination affects perceived size and distance: A replication and extension of Wallach and O'Leary (1982).** Morgan Williams[1](mwillia2@swarthmore.edu), Frank Durgin[1]; [1]Department of Psychology, Swarthmore College

Wallach and O'Leary (1982) were the first to argue that 'slope of regard' (or gaze declination) was a distance cue. In three experiments, Wallach and O'Leary used an inverted Galilean telescope (GT) with horizontally oriented cylindrical lenses to manipulate perceived slope of regard when viewing a square, vertical object resting on the floor. Unlike prism goggles, which shift the entire scene angularly, their GT, which was mounted horizontally, maintained the visual horizon as straight ahead but compressed apparent gaze/angular declination and elevation relative to that horizon. Because of this their GT did not alter the perceived orientation of the ground plane as base-up prisms would. They used perceived object width (matched with an extendable hand-held rod) as an indirect measure of perceived distance and concluded that optically compressing slope of regard (toward horizontal) made objects on the floor appear farther away and thus wider than they were. We replicated their basic experimental manipulation and reproduced their principal finding that perceived object width was increased. However, concerned that their result could be interpreted as affecting size alone (e.g., via the horizon ratio), we sought to extend their study by collecting both explicit verbal distance estimates and implicit action measures of distance (distance thrown, when throwing to a target). Participants ($N = 44$) looked through an eye-level GT with a vertical compression ratio of 0.7 or through the same device without any lenses into a well-lit room. On the floor was a horizontal target 6 m away. Both explicit distance estimates and the beanbag toss distances (order counterbalanced) were affected by perceived slope of regard consistent with the predicted change in perceived distance. In summary, a direct optical distortion of angular declination without a change in the perceived horizon affects perceived distance as measured both by action (throwing) and by explicit estimation.

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23.532 **Extending Size Constancy Illusions from 2-D to 3-D Stimuli** Joshua Dobias[1](jjd242@rci.rutgers.edu), Anuja Sarwate[1,2], Thomas Papathomas[1,2]; [1]Laboratory of Vision Research, Center for Cognitive Science, Rutgers University, NJ USA, [2]Department of Biomedical Engineering, Rutgers University, NJ USA

Objective: Size constancy illusions are typically demonstrated using 2D stimuli in which one object is perceived as further than another despite being at the same distance. Our objective was to extend these findings

using 3D reverse-perspective (RP), forced-perspective (FP), and flat stimuli (2D). Methods: In two experiments, observers viewed stimuli that had painted linear perspective cues that were either congruent (FP) or incongruent (RP, 2D) with the physical geometry. The RP stimulus was bistable (veridical or illusory), whereas FP and 2D only afforded one percept. Observers were asked to estimate the perceived size of a probe (disk or person) placed in one of two locations, by adjusting size of a second sample probe. In Experiment 1, observers were told that the stimulus could be bistable, were showed the two possible percepts, and were asked to adjust the probe when the percept was stabilized. In Experiment 2, new observers viewed the FP and RP stimuli, but were not told that RP could be bistable. Results and Discussion: In Experiment 1, person probes placed at the "more distant" position - as defined by the perspective cues - were perceived as larger for all stimuli, whereas disk probes were only perceived as larger at the "more distant" position for the 2D stimulus. Surprisingly, when perceiving the veridical shape of the RP stimulus, observers reported the "more distant" probe to be larger despite it being perceived to be closer, suggesting that observers continue to use the monocular perspective cues despite having binocular cues that provide reliable distance information. In Experiment 2, when observers were not told that the stimuli were bistable, observers again perceived the "more distant" test probe to be larger for FP and RP stimuli. In both experiments, observers were more accurate in judging the size of the disk than the human figure.

23.533 **Electrophysiological correlates of size constancy** Irene Sperandio[1](irene.sperandio@gmail.com), Juan Chen[2], Melvyn Goodale[2]; [1]School of Psychology, University of East Anglia, Norwich, UK, [2]The Brain and Mind Institute, The University of Western Ontario, London, Ontario, Canada

Size constancy is the ability of the visual system to achieve a stable experience of perceived size despite the fact that the image projected onto the retina varies continuously with viewing distance. To compute the perceived size of an object, our visual system needs to combine together retinal image size with distance information. To date, there has been little investigation on the neural mechanisms that underlie size constancy in the human brain in a situation in which the real, rather than the apparent, distance of the stimulus is manipulated. In the present study, event-related potentials (ERPs) were measured to investigate the temporal dynamics of size-distance scaling. The viewing distance and the retinal image size of a series of filled black circles were varied to create four experimental conditions: 'small-near', 'big-near', 'small-far', and 'big-far'. The critical conditions were those in which the stimuli were perceived as different in size but subtended the same retinal angle as a result of their different distance from the observer (i.e. 'small-near' vs. 'big-far') as well as those in which the stimuli were perceived as constant but their retinal image size decreased with distance (i.e. 'small-near' vs. 'small-far', 'big-near' vs. 'big-far'). Participants were asked to maintain their gaze steadily on a fixation point throughout the experiment while EEG was recorded from 28 scalp electrodes. We focused on the first visual evoked ERP component peaking at approximately 100 ms after stimulus onset. We found earlier latencies in response to larger than smaller stimuli, regardless of their distance. Moreover, we observed that the amplitude was greater in the far than in the near condition, regardless of stimulus size. These findings provide novel evidence that size constancy involves operations that take place at the earliest cortical stages in conditions in which the real, rather than the apparent, distance changes.

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23.534 **Depth detection thresholds for disparate subjective occluders decrease with inducer entropy.** Barbara J Gillam[1](b.gillam@unsw.edu.au), Barton L Anderson[2]; [1]School of Psychology, University of New South Wales, Australia, [2]School of Psychology, University of Sydney, Australia

Gillam and colleagues (e.g. Gillam and Grove, JEP 2011) found that (monocular) subjective contours along linearly aligned edges are much stronger when the inducers vary, for example in size, separation and orientation, than for regular inducers. A smooth linear alignment for otherwise unrelated inducers ("entropy contrast") is powerful evidence for occlusion. However the methods used, such as paired comparison and ratings, may allow a possible subjective influence. Here we use similar figures, each comprised of 5 aligned rectilinear shapes, in a stereoscopic occlusion detection task, which provides an entirely non-subjective evaluation of the power of entropy in inducing subjective contours along linear alignments. Thresholds for detecting the presence of a subjective occluder in depth were obtained using a Quest procedure with two alternative forced choice. One of two successive stimuli on each trial had the depth step. The planar inducing figures were tilted 45 degrees with a 45-degree alignment. Depth steps were created by a small expansion of the inducers in one eye in a 45-degree direction producing both vertical and horizontal disparities at the alignment. Thresholds were obtained for three sets of inducers (a) orthogonal to the alignment and completely regular in size and separation (b) orthogonal but irregular in height, width and separation (c) irregular in these properties as well as orientation. Support ratio and size/orientation properties were controlled for. For inducers varying in orientation, both disparities varied across inducers, adding depth entropy to other entropies. Mean depth thresholds across the 9 observers were 10.5, 8.3 and 3.6 arcmin respectively for the 3 inducer types with an ANOVA showing all differences to be highly significant. Thus depth detection thresholds decreased with increasing inducer entropy. In a second experiment we showed that the entropy effect could not be accounted for by the relative magnitudes of vertical and horizontal disparity

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23.535 **What is stable in visual stability?** Andrew Glennerster[1](a.glennerster@reading.ac.uk); [1]School of Psychology and Clinical Language Sciences, University of Reading

In the literature on visual stability, most studies focus on the problem of relating two retinal images, one before and one after a saccade. The more general problem of achieving visual stability over a number of saccades or for a freely moving observer requires a different solution. The answer must lie in one of two categories: visual stability could result from the generation of an unchanging representation of the scene despite head and eye movements, or it could reflect an ability to predict the sensory consequences of actions (including saccades and head movements) without relying on a stable, Cartesian representation of the scene. The former approach entails 3D coordinate transformations as an observer moves their head and eyes; the latter requires a large storage capacity. Examination of the storage-based approach leads to a change in perspective for other visual problems. For example, under this model, retinal flow should not be decomposed into rotational and translational flow. That might be useful for extracting 3D structure and observer movement in a stable coordinate frame but it is not appropriate if the purpose of retinal flow analysis is to determine the trajectory along an expected path of images. As observers carry out tasks, their sensory+motivational state moves along an expected path. Task-dependent paths are built up gradually through evolution and development. The experience of visual instability would arise only when the expectation is confounded. Results such as the apparent stability of an expanding virtual room (Glennerster et al 2006, Current Biology) can be explained within a storage-based framework but are more difficult to account for on the basis of Cartesian scene representation. Overall, if we are to make progress in understanding visual stability, we must be clear what the problem is that needs to be solved.

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23.536 **Which way is up in the horizontal-vertical illusion?** Brennan Klein[1](bklein2@swarthmore.edu), Zhi Li[1], Durgin Frank[1]; [1]Department of Psychology, Swarthmore College

Very large horizontal-vertical illusions (HVI) may be observed in outdoor scenes, such that horizontal extents must be made as much as 25% longer to seem equal to vertical extents (Chapanis & Mankin, 1967). Here we ask whether these effects are referenced to the orientation of the observer or the world and whether they are affected by the extent of one's horizontal field of view (FOV). Forty-eight participants viewed poles, 3-9 m in height, from a distance of 15 m. Half viewed the poles while lying on their side at eye-level. Half stood upright. In each group, half wore a patch over one eye to reduce their FOV. The task was to instruct the experimenter to adjust the horizontal distance to a second pole until that distance matched the height of the observed pole. Adjustments were made from close and far starting positions, and the average matches were analyzed. In the upright condition we replicated very large HVI matches (1.25) for objects of 6 m or more. Across all pole heights, HVI matching ratios were larger for upright observers (1.2) than for sideways observers (1.1), $p < .01$, but remained primarily yoked to the world vertical rather than the bodily vertical. Across both viewing orientations, HVIs differed by pole height, $p < .0001$, increasing from about 1.1 for shorter poles to 1.2 for taller ones. There were no effects of FOV (binocularity). In a follow-up study simulating a similar outdoor scene in immersive VR, we rotated the world instead of the observer, and this produced essentially the same results as rotating the observer in the real world. These rotation results can be modeled by assuming a small (e.g., 5%) HVI illusion tied to the body and a larger (e.g., 15%) HVI illusion tied to a ground-plane-defined world orientation.

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 See page 3 for Abstract Numbering System

23.537 **Water Flows Uphill: A Visual Illusion and Its Explanation**
Wenxun Li[1](wl18@columbia.edu), Ethel Matin[2], Leonard Matin[1]; [1]Department of Psychology, Columbia University in the City of New York, [2]Department of Psychology, Long Island University – Post

A pitched visual field influences the perceived elevation of objects within the field and the elevation visually perceived as eye level, VPEL (reviewed in Matin & Li, 2010). In the present report we show that a pitched stationary inducer also produces changes in the perceived direction of motion (no movement of the inducer is involved). Specifically: a stream of water that is physically flowing downhill in a transparent linear tube appears to flow uphill when it is viewed against a stationary topbackward pitched visual field. Data showing the magnitude of the illusion with parametric variation of pitchroom orientation and tube orientation will be presented. At the poster we will provide a demonstration of the illusion with a topbackward pitched visual field that induces a 12o downward displacement of VPEL. We explain the upward direction of perceived water flow by combining two facts: (1) pitching a visual field changes the elevation of VPEL, and (2) the illusory uphill water flow occurs when the tube is set in a surface between the horizontal surface containing true eye level and the surface containing VPEL.

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23.539 **Short-term visual memory for stereoscopically-defined depth**
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Last year we reported that the short-term memory for stereoscopically defined depth, measured as the partial report accuracy for reporting the identity of a numeral in a cued depth plane, drops for the first 200 ms or so, then slowly recovers almost back to its starting point. To explain this dip in performance we proposed a two-memory model in which depth information suffers a rapid sensory ('iconic') decay in STVM, as is typical for many other visual features, but is also transferred slowly to a visual working memory. The transfer to working memory improves with several hours of practice, leveling out the dip. We now report that the dip is specific to a visual cue, an arrow in the same depth plane as the to-be-reported numeral; with a tonal cue, whose frequency specifies the depth plane, even inexperienced subjects show no such dip. We speculate that attention to the visual cue slows transfer to visual working memory, perhaps because matching the depth of the arrow to the depth of the target numeral is taxing, even when the depth planes are clearly distinct.

23.540 **Effect of Different Directions of Attentional Shift on Inhibition of Return in Three-dimensional Space**
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When attention is oriented to a peripheral cue, there is facilitation of processing of nearby stimuli. The brief period of facilitation is followed by a long-lasting inhibitory effect in which there is delayed responding to stimuli presented at subsequently cued location. Although it has been documented that the mechanisms underlying the earlier facilitatory effect of attentional orienting in three-dimensional space (3D) (Chen et at., 2012), it remains poorly understood how visuospatial attention is shifted in depth at the later inhibitory phase. In the present study, by incorporating the Posner exogenous cueing paradigm into a virtual 3D environment, we aimed at investigating the influence of different direction of attentional shift along the depth dimension on inhibition of return (IOR). We presented targets either close to or far from the participants and manipulated the validity of cues to construct different direction of attentional shift [targets appeared in the same as location of the cues, Within_Valid (WV); targets appeared in the depth plane that the cues located to, but in the opposite hemispace, Within_Invalid (WIV); targets appeared in the uncued depth plane, but at the same hemispace of the cue, Between_Invalid_Same_Hemispace (BIV_SH); targets appeared not only in the uncued depth plane, but also in the opposed hemispace, Between_Invalid_Different_Hemispace (BIV_DH)]. The results showed that RTs in the WV condition (valid) were significantly slower than RTs in the WIV and BIV_DH (invalid) condition, i.e. a typical IOR, regardless of whether the target appeared in the closer or farther depth plane. However, when attention reoriented along the conditions of BIV_SH, there were typical IOR when targets appeared only in closer depth plane, but not in farther depth plane. Taken together, we showed that attentional reorienting in depth operates as efficiently as in the bi-dimensional space just only when objects that unexpectedly approach observers.

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23.541 **Visual image encoding and transformation processes in three dimensional immersive virtual environments**
Maria Kozhevnikov[1](psymaria@nus.edu.sg); [1]Psychology Dept., National University of Singapore

Three-dimensional immersive (3DI) virtual reality environments are being increasingly used in visual cognition research. Yet, little is known about the neural substrates of visual processing within immersive environments neither natural nor virtual. Currently, most human visual processing research has been conducted using non-immersive computer displays. In an immersive environment the observer perceives herself as being surrounded by a 3D world. In contrast, in a non-immersive environment (i.e.traditional computer display, either 2D monocular or 3D-stereoscopic), the observer is placed outside of the scene looking in. In this study, we investigated how individuals encode and transform visual images within 3DI environments. In Experiment 1, we compared participants' performance on the mental rotation task across three types of environments; traditional 2D non-immersive (2DNI), 3D non-immersive (3DNI – anaglyphic glasses), and 3DI (head mounted display with position and head orientation tracking). In Experiment 2, we compared electroencephalogram data recorded while participants were mentally rotating visual images presented in 3DI vs. 2DNI environments. Only in the 3DI environment, the rate of rotation in the picture plane was significantly faster than that in horizontal depth, suggesting that participants were encoding 2D retina-based visual representations in relation to a viewer-centered frame of reference since only then would depth rotation take longer than rotation in the picture plane, due to occlusion. Furthermore, 2DNI and 3DI environments did evoke differential parietal ERP responses, and that ERPs were more negative at~270–300ms post-stimulus for MR in the 3DI vs. 2DNI environment. We suggest that this early modulation of ERP activity marks viewer-centered vs. scene-based orienting in preparation for subsequent rotation from 400ms onward. Overall, the results suggest that in a non-immersive environment, participants may utilize a scene-based frame of reference and allocentric encoding whereas immersive environments may encourage the use of a viewer-centered frame of reference and egocentric encoding.

Acknowledgement: Office of Naval Research

23.542 **Does gaze declination contribute to shape constancy on level ground? A comparison of perceived shapes on outdoor hills and fields**
Zhi Li[1](zhi.li.sh@gmail.com), Frank Durgin[1]; [1]Department of Psychology, Swarthmore College

According to scale expansion theory two distinct sources of angular information are used to compute distance along the ground and shape on the ground: (1) angular (or gaze) declination is used to estimate egocentric ground distance, and (2) optical slant information is used to compute shape (Li & Durgin, 2010, 2012). Texture and binocular information both contribute to optical slant estimation when gaze is forward. Here we ask whether gaze declination also contributes to shape estimation on the ground plane. On the one hand gaze declination is an excellent estimate of the optical slant of a fixated surface on level ground. On the other hand, estimates of gaze declination and of optical slant need to be used conjointly to estimate geographical slant, so using one to estimate the other would seem inadvisable. To test this experimentally, we assumed that if gaze declination is used to help recover shape on level ground, then shape constancy should be enhanced for objects on level rather than slanted ground. Participants judged the aspect ratios of L-shaped configurations of white balls presented either on level ground (gaze declination informative) or on one of three hill surfaces viewed at eye level (gaze declination not informative) in an outdoor environment. The optical slants (6°, 22° and 35°) and viewing distances used were matched in the two conditions. The results indicated partial shape constancy failure in all conditions. Shape constancy was better for smaller viewing distances and for larger optical slants, but there were no differences in mean judged aspect ratios between matched level ground and hill conditions. Nor was the variance of shape estimation reduced on level ground. These results suggest that the gaze declination information that is available when observing configurations on level ground does not contribute to the perception of shape.

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23.543 **Angular expansion theory turned on its side** Frank Durgin[1](fdurgin1@swarthmore.edu), Zhi Li[1], Brennan Klein[1]; [1]Department of Psychology, Swarthmore College

When standing, egocentric distance can be specified angularly by direction of gaze to the point of ground contact (Wallach & O'Leary, 1982). Estimates of egocentric distance show underestimation by 0.7, consistent with an observed overestimation of gaze declination by 1.5 (Durgin & Li, 2011). Moreover, perceptual matching of ground distances to pole heights can be perfectly modeled by a 1.5 expansion of perceived angular declination relative to the horizontal (Li et al., 2011). In azimuth, extent matching corresponds to an angular expansion of about 1.2 (Li et al., 2013). Are these angular biases associated with the coding of gaze position in the head or with the reference frame of the horizontal ground plane? We tested this question in an open field using people as targets by comparing perceptual matching by upright observers and by observers suspended on their sides at eye level. Participants instructed one experimenter to move left or right so as to create a frontal distance from a second experimenter equal to the participant's egocentric distance to the second experimenter. Implicitly, the task is to create a 45° azimuthal angle. Would matches made by observers on their side show an angular gain of 1.5, consistent with their bodily orientation, or would they show the more typical azimuthal gain of 1.2? A total of 35 participants (18 sideways) matched egocentric distances of 7 to 16 m and made verbal estimates of a 35 m egocentric extent and a 25 m frontal extent 35 m away. In fact, participants on their side showed twice the angular bias as upright participants -- both in their extent matches and in their verbal estimates of distances. The sideways verbal estimates implied an angular expansion by 1.4. These angular distortions do not seem to affect shape perception, but only the estimation of extents between objects.

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Visual memory: Mechanisms and models

Saturday, May 17, 8:30 am - 12:30 pm
Poster Session, Pavilion

23.544 **Guidance of object-based attention from neural signatures of memory** J. Benjamin Hutchinson[1](jhutchin@princeton.edu), Nicholas B. Turk-Browne[1]; [1]Department of Psychology, Princeton University

We are constantly exposed to numerous objects vying for limited processing resources. Such competition is thought to be resolved based on bottom-up salience and top-down goals, but a growing body of research suggests that past experience stored in memory can also play an important role in shaping attentional priorities. In a previous fMRI study, we showed that such memory-guided attention is supported by repetition attenuation — the lower fMRI response elicited by repeated vs. novel stimuli. When a repeated scene and a novel scene were presented simultaneously at different locations, the attenuated response for the repeated scene enhanced processing of the novel scene. In the present study, we replicated these findings using a task that allowed for better neural separation between the novel and repeated objects by selecting them from different categories. This also allowed us to generalize from spatial to object-based attention. Each trial began with two presentations of the same face at fixation. In the repeated/novel condition, the face was presented a third time in competition with a surrounding novel scene. The novel/novel condition was identical, except a novel face appeared with the scene instead of the repeated face. We later tested long-term memory for the scenes to index how well they were processed. Two results suggested that repetition attenuation for the face biased processing toward the scene: First, there was a negative correlation across trials between activity in face-selective cortex during the competitive event and subsequent memory for the scene. Second, this relationship was found in the repeated/novel but not the novel/novel condition. Whereas most studies of repetition effects focus on the processing of repeated or similar stimuli, here we show broader consequences for the processing of unrelated stimuli. Specifically, these expressions of perceptual memory automatically bias competitive dynamics in the visual system to highlight new information.

Acknowledgement: JBH: F32 EY021999 NTB: R01 EY021755

23.545 **Practice abolishes similarity's influence on VSTM-induced interference on perception** Nicholas M. Van Horn[1](van-horn.73@osu.edu), Alexander A. Petrov[1]; [1]Department of Psychology, Ohio State University

Recent work on visual short-term memory (VSTM) has revealed that visual input is subject to modulation by the contents of VSTM. According to the sensory-recruitment model of VSTM, this interaction, and the related phenomenon of memory masking, is explained in terms of overlapping neural populations. The current study demonstrates that VSTM's influence on the current visual percept is not set by a fixed limit, but rather can be reduced with training. Method: Seventeen observers trained for six one-hour sessions to memorize the orientation of a sample Gabor and reproduce it 4.25 seconds later by rotating a match Gabor. During the retention interval, observers also completed a binary orientation-discrimination task with a target Gabor. Adaptive methods estimated discrimination psychometric functions across training sessions. In one group, the mean orientation of the memory sample during training was identical ("congruent") to the discrimination boundary. In the other group ("incongruent"), the orientations were orthogonal. Both groups completed pre- and post-tests in which the sample orientation, and therefore the congruency condition, was switched. Results: Discrimination thresholds were initially worse for incongruent than congruent trials, indicating VSTM-induced influence on perceptual representations. This difference diminished quickly with practice, and both congruency groups reached identical asymptotic performance (discrimination threshold of 7 degrees at 84% correct). Post-tests indicated that improvements on incongruent stimuli transferred almost completely to congruent stimuli, whereas improvements on congruent stimuli were almost completely specific. Discussion: These results support recent studies indicating VSTM-dependent changes in perception during the memory retention interval, and provide the first evidence that similarity-based differences in the amount of interference can be eliminated with training. The greater interference observed for incongruent stimuli challenges traditional interpretations of similarity's role in the interaction between VSTM and perceptual representations.

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23.546 **Bayesian adaptive estimation of the sensory memory decay function: the quick Partial Report method** Jongsoo Baek[1](baek.83@osu.edu), Luis Lesmes[2], Zhong-Lin Lu[1]; [1]Laboratory of Brain Processes (LOBES), Departments of Psychology, The Ohio State University, Columbus, OH, [2]Adaptive Sensory Technology, Boston, MA

Sensory memory is the literal, modality-specific neural representation of sensory stimuli in the human brain. It provides the initial copy of external stimulation to human sense organs that can be processed by subsequent stages of perception and cognition. Recent studies suggest that sensory memory decays much faster for observers with mild cognitive impairment and may serve as an early sign of the Alzheimer's disease. In the visual modality, iconic memory is best assessed with the partial report procedure. In this procedure, an array of letters appears briefly on the screen. A post-stimulus cue directs the observer to report the identity of the cued letter. Typically 600-800 trials are tested to measure the sensory memory decay function. The long testing time has prevented wide use of the test in clinical settings and special populations. Here we develop a quick partial report or qPR procedure based on a Bayesian adaptive framework to estimate the sensory memory decay function with much reduced testing time. Starting with a prior distribution of the parameters, the method selects the stimulus to maximize the expected information gain in the next trial. It then updates the probability distribution of the parameters based on the observer's response by Bayesian inference. The procedure is iterated until the total number of trials reaches a set value. Simulation studies suggest that only 100 trials are necessary to reach accuracy of .47dB and precision of 2dB. The method was validated in a psychophysical experiment. Estimates of the sensory memory decay function obtained with 100 qPR trials showed good precision (SD = .55dB) and excellent agreement with those obtained with 1600 trials using the conventional procedure (mean RMSE = .48dB). qPR relieves the data collection burden in characterizing sensory memory and makes it possible to assess sensory memory in clinical settings and special populations.

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23.547 **The uninformativeness of summary statistics for comparing working memory models** Wei Ji Ma[1](weijima@nyu.edu), Ronald Van den Berg[2]; [1]Center for Neural Science and Department of Psychology, New York University, [2]Department of Electrical Engineering, University of Cambridge

Performance on visual working memory tasks decreases as more items need to be remembered. Over the past decade, a debate has unfolded between proponents of "slot models" and "slotless models" of this phenomenon. Zhang and Luck (2008) and Anderson et al. (2011) notice that as more items need to be remembered, "memory noise" seems to first increase and then reach a "stable plateau". They argue that three summary statistics characterizing this plateau are consistent with slot models, but not with slotless models. Here we assess the validity of their methods. We generated synthetic data both from a leading slot model and from a recent slotless model, and quantified model evidence using log Bayes factors. We found that the summary statistics provided at most 0.15% of the expected model evidence in the raw data. In a model recovery analysis, a total of more than

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a million trials were required to achieve 99% correct recovery when comparing models based on summary statistics, whereas fewer than 1000 trials were sufficient when using raw data. These results show that using plateau-related summary statistics for model comparison is highly inefficient, and unreliable for realistic numbers of trials. Applying the same analyses to subject data from Anderson et al. (2011), we found that the evidence in the summary statistics was at most 0.12% of the evidence in the raw data and far too weak to warrant any conclusions. These findings call into question claims about working memory that are based on summary statistics.

23.548 **Models of color working memory with color perception as a variable** Gi-Yeul Bae[1](freebird71@gmail.com), Maria Olkkonen[2], Sarah Allred[3], Colin Wilson[1], Jonathan Flombaum[1]; [1]Johns Hopkins University, [2]University of Pennsylvania, [3]Rutgers-The State University of New Jersey

Surprisingly, the rapidly expanding literature on models of color working memory (CWM) has made little contact with research on color perception. With the aim of integrating these literatures, we applied standard color perception methodology to an influential CWM task. First, we scrutinized methodological practice for color rendering. Published CWM research typically specifies colors in CIELAB space, but does not verify that produced color coordinates match those requested. When we applied standard calibration procedures to our display, we discovered that typical CWM methods produce colors that vary considerably in luminance, and that many were out of gamut. Thus the space from which colors were sampled was not a ring, undermining the common practice of collapsing across trials with different colors when estimating model parameters. Next, we generated a CIELAB color ring with fixed luminance, and we verified that color rendering was accurate. With this color ring, we looked for color-specific variability in memory and perception. We found considerable color-dependent variability in response dispersion (precision) and central tendency (bias) in two delayed-estimation experiments. Color-specific variability in memory correlated significantly between observers and memory loads. Moreover, it correlated with the perceptual variability obtained in a third experiment without a delay. Finally, we investigated potential interactions between color memory and color categories defined by verbal naming. In two experiments, observers identified focal colors and category boundaries. We found that response precision and bias may depend on category representations associated with remembered colors. Using these empirical results, we developed several new models of CWM that include category-influenced effects, as well as binding computations relying on categorical similarity. These results suggest a reevaluation of previous CWM models. More broadly, they suggest that not all colors are structured identically in color working memory; instead, both perceptual and memory representations vary in complex ways throughout color space.

23.549 **The Binding Pool model of VWM: A model for storing individuated objects in a shared resource pool** Garrett Swan[1](gsp.swan@gmail.com), Brad Wyble[1]; [1]Psychology, Liberal Arts, The Pennsylvania State University

Two prevalent models that describe Visual Working Memory (VWM) assume that information is either stored in discrete slots or within a shared resource pool. To develop the theoretical landscape further, we propose a hybrid model called the Binding Pool model. This model details how multiple items can be encoded and retrieved individually yet interact with one another in a distributed binding pool using a Type/Token architecture. These processes use simple neural mechanisms that can rapidly encode arbitrary connections between different features (types), a location, and an object-file (token). These connections are stored by accumulating and storing simulated neural activity in a set of neurons called the binding pool. The model provides a unified framework for understanding VWM capabilities as measured by change detection and continuous report tasks. The Binding Pool model also provides a mechanism for explaining simple ensemble effects, such as the shifting of a stored representation towards another (Huang & Sekular, 2010). This arises because tokens share representational space in the binding pool, creating crosstalk between two stored items. The Binding Pool model can also generate predictions, which simultaneously test the validity of the model and may help to drive further research. One prediction of the model that was recently confirmed is increased precision in a directed forgetting paradigm in which participants are instructed to forget a specific stimulus. In a forgetting trial, the precision of the remaining stimulus is higher relative to a non-forgetting trial, but this precision is still lower than precision of a representation in a single item trial. (Williams, Hong, Kang, Carlisle, & Woodman, 2013). In the model, reducing the activity of binding pool neurons connected to the forgotten item, reduces interference during retrieval, which enhances precision of the remaining items. The model also predicts that encoding more features per item reduces precision.

23.550 **Compensation Mechanisms for Poor Filtering Ability in Visual Working Memory** Ayala S. Allon[1](ayalaall@post.tau.ac.il), Roy Luria[1,2]; [1]The School of Psychological Sciences, Tel-Aviv University, [2]The Sagol School of Neurosciences, Tel-Aviv University

Visual Working Memory (VWM) is a temporary storage that can hold a limited amount of information (between 3-4 objects). Despite its limited capacity, there are robust and reliable individual differences in VWM capacity that correlate with important aptitude measures. In an attempt to understand the nature of these differences, Vogel et al. (2005) argued that filtering efficiency (i.e., the ability to ignore task irrelevant items) might explain individual differences in VWM capacity. They showed that filtering efficiency is highly correlated with VWM capacity, such that low-capacity individuals demonstrated poor filtering efficiency relative to high-capacity individuals. However, it is not clear how low-capacity individuals cope with our daily environment which is crowded with irrelevant information. Note that in previous studies, filtering trials were presented completely at random. Therefore, one option is that when the need to filter out information is known in advance, low-capacity individuals can compensate and perform better. In the current study we investigated the connection between VWM capacity and the ability to control filtering efficiency using a change-detection task modeled after Vogel et al. (2005) while ERPs were recorded. Participants viewed memory arrays that included either two targets, four targets, or two targets and two distractors (the filtering condition). However, filtering trials always appeared in pairs, such that while the first filtering trial remained random, the second one was 100% predictable. In separate experiments we either did or did not explicitly tell that to participants. We used the CDA (which is a waveform of the event-related potential that reflects the number of items encoded and maintained in VWM) to monitor changes in filtering efficiency. In both experiments we found no difference between the first (random) and the second (predictable) filtering trials suggesting that prior knowledge about when filtering occurs did not compensate for poor filtering efficiency in VWM.

23.551 **When common-fate fails: The limited reach of Gestalt grouping cues in online object binding in visual working memory** Halely Balaban[1](halelyba@mail.tau.ac.il), Roy Luria[1,2]; [1]The School of Psychological Sciences, Tel-Aviv University, [2]The Sagol School of Neuroscience, Tel-Aviv University

The question of what makes a visual object is both intriguing and elusive. Using the contralateral delay activity (CDA), an ERP component sensitive to the number of objects represented in visual working-memory (VWM), we tested the effects of Gestalt grouping cues on the binding of features from different dimensions. Participants performed a change-detection paradigm, in which "objecthood" was manipulated using shared location and common-fate grouping cues across 4 experiments. In Experiment 1, stationary colors and orientations were presented in 3 conditions: 2 items in 2 separate locations, 4 items in 4 separate locations, and 4 items in 2 separate locations (creating 2 color-orientation conjunctions grouped by a shared location cue). The results suggested that sharing a location did not lead to an integration of the color and orientation to one object in VWM as indicated by the CDA. In Experiment 2, the colors and orientations moved for 1000 ms, either together or independently, and then remained stationary for 100 ms. There were 4 conditions: 2 separate items, 4 separate items, 2 "common-fate" items (i.e. 4 items creating 2 color-orientation conjunctions that moved together), and 4 separate items meeting to create 2 color-orientation conjunctions. Interestingly, even a common-fate grouping cue did not result in the binding of color and orientation. To further investigate the failure in binding features from different dimensions, we replicated these two experiments, using familiar shapes instead of orientations. In Experiment 3, colors and shapes were not integrated in VWM when they shared the same location. However, in Experiment 4, colors and shapes moving together were represented as integrated objects in VWM. Our results suggest that a potent Gestalt grouping cue of common-fate does not produce reflexive binding. Instead, binding also depends on the type of objects and presumably their familiarity.

23.552 **Neural Signatures of Visual Memorability: Memory in the First Perception of an Image** Wilma A. Bainbridge[1](wilma@mit.edu), Aude Oliva[2]; [1]Department of Brain and Cognitive Sciences, MIT, [2]Computer Science and Artificial Intelligence Laboratory, MIT

Whereas some places or people leave a memorable first impression, others are immediately forgotten. Recent work has shown that memorability of scene and face pictures is highly consistent across people, providing a basis to predict later memory behavior (Bainbridge, 2013; Isola, 2011). Here, we investigate the neural signatures of memorability during the first percep-

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tion of an image. In two fMRI experiments, participants were shown blocks of novel images grouped by stimulus type (face or scene) and memorability level (high or low memorability). Stimuli were carefully controlled for attributes including gender, race, attractiveness and emotional content for faces, and indoor/outdoor, natural/manmade and category type for scenes, as well as a range of low-level image statistics for both. To validate the robustness of the findings, different sets of participants performed a 1-back task in Experiment 1 (N=24) and a perceptual task in Experiment 2 (N=13). None were told about the memory-related nature of the study. For each participant, independent functional localizers were used to localize perceptual regions, and regions in their medial-temporal lobe (MTL) were segmented using anatomical landmarks. Whole-brain analyses, multivariate analyses, and region of interest analyses pinpointed areas of responsiveness to memorable versus forgettable images. In both experiments, signatures of memorability were not found in low-level visual areas, but were consistently found in several perceptual regions specific to faces and scenes. Different regions in the MTL (e.g., the perirhinal cortex) also show preferential activity for memorable images, regardless of the stimulus type. Multivoxel pattern analyses reveal pattern encoding of more memorable items, after a single exposure, in the hippocampus. These results show that signatures of memorability of an image can be found both in ventral neocortical and medial temporal lobe regions, questioning to which extent perception and memory representations are separated in the brain.

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23.553 **Dissociable Neural Mechanisms for Capacity & Resolution in Visual Working Memory** Marcus Cappiello[1](mcapp001@ucr.edu), Weizhen Xie[1], Weiwei Zhang[1]; [1]Psychology, University of California, Riverside

The capacity and resolution of visual working memory (VWM) representation reflect two independent sources of limits on working memory storage. The relationships between the two factors have been the subject of considerable controversy. According to the discrete slot model, VWM stores a limited set of discrete, fixed-resolution representations. A key prediction of this model is the dissociations of VWM capacity and resolution. In sharp contrast, the flexible resource model predicts a tradeoff between VWM capacity and resolution. That is, the amount of resources each representation gets can be flexibly varied so that either a larger number of coarse-grained representations or a smaller number of fine-grained representations can be retained in VWM. Previous research with behavioral approaches has demonstrated VWM capacity and resolution can be operationally defined and experimentally manipulated in independent manners, providing some support for the slot model. However, it becomes difficult to distinguish the two competing models with behavioral methods alone when multiple slots are averaged to represent a single memory item in order to boost resolution at the cost of capacity. The present study used non-invasive brain stimulation techniques to test whether there are dissociable and independent neural mechanisms for VWM capacity and resolution. In two experiments, VWM was tested in a color recall task in which observers attempted to retain several colors in VWM over a 1-s retention interval and then recalled one of them by clicking on a color wheel. In Experiment 1, bilateral transcranial Direct Current Stimulation (tDCS) over the anterior temporal lobes induced a virtual lesion in resolution with intact capacity. In Experiment 2, alpha-band transcranial Alternating Current Stimulation (tACS) over the posterior parietal cortex selectively enhanced capacity with intact resolution for ipsilateral stimuli compared to contralateral stimuli. Taken together, these results have demonstrated dissociable neural mechanisms for VWM capacity & resolution.

23.554 **The Neural Fate of Individual Item Representations in Visual Working Memory** Gennadiy Gurariy[1](genaxl@yahoo.com), Dwight Peterson[1], Marian Berryhill[1], Gideon Caplovitz[1]; [1]University of Nevada, Reno

Visual working memory (VWM) stores information from the visual world. Despite its importance in a variety of cognitive tasks, this process appears to be capacity limited to approximately 3 or 4 items. Previous studies examining the sources of this capacity limitation have largely focused on the maintenance phase of VWM. Here we investigate the possible role of the encoding phase of VWM as a potential source of capacity limitation. In the present study we addressed this question by examining the neural fate of an item through the measurement of activity during VWM encoding phase. We hypothesized that a greater amount of limited capacity neural resources at the time of encoding are needed to facilitate subsequent retrieval of the item. We tested this hypothesis using frequency tagging and EEG. For each trial, four novel shapes were presented. Each shape flickered at one of four distinct frequencies. After a blank delay period a single, static shape appeared at one of the previous locations. Participants were to respond whether the test item was "old" or "new". For each condition the amplitudes of the corresponding fundamental frequency and second harmonic (frequency tags) were extracted from the frequency spectrum. The amplitudes of the second harmonics corresponding to the probed item, measured at Parietal (P7/P8) and Central (C7/C8) electrode sites, were greater for correct than incorrect trials. The data support the hypothesis that neural resources allocated to individual items at the time of encoding play an important role in in the overall capacity limitations of VWM.

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23.555 **The effect of biased competition within sequential displays on visual short-term memory** Claire E. Miller[1,4](claire.miller@bangor.ac.uk), Niklas Ihssen[2,3], David E. J. Linden[2,3], Kimron L. Shapiro[4]; [1]School of Psychology, Bangor University, [2]School of Psychology, Cardiff University, [3]Institute of Psychological Medicine and Clinical Neurosciences, School of Medicine, Cardiff University, [4]School of Psychology, University of Birmingham

Much has been discovered about the properties of visual short-term memory (VSTM), but few mechanisms have been proposed to explain limitations such as its low maximum capacity (Luck & Vogel, 1997). One mechanism suggested to account for this outcome is that of biased competition (Desimone & Duncan, 1995), with growing evidence suggesting that increasing competition in early visual areas may result in fewer stimulus items being successfully recalled (Shapiro & Miller, 2011). It has previously been shown that VSTM performance on a change detection task can be enhanced by reducing competition, through dividing the to-be-remembered items into two sequential displays (Ihssen, Linden & Shapiro, 2010). However, the episodic nature of the sequential displays may also have benefitted VSTM (see Bowman & Wyble, 2007). The present study provides further support for the biased competition account by manipulating competition whilst holding constant the number of episodes in which the stimuli were presented. Using a modified change-detection task the ratio of items between two displays was varied between n : n (the same number of items in each display) and n : n+/-3 (three more items in one display), for displays of both low (4-5 items) and high set size (7-8 items). We found significantly higher k-values for the near ratios (n : n and n : n+/-1) than the far (n : n+/-2 and n : n+/-3). There was no significant main effect of set size, nor interaction. These results provide compelling evidence that inter-stimulus competition plays a role in VSTM.

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23.556 **Fine-grained representation of visual object information retrieved from long-term memory** Sue-Hyun Lee[1](lees11@mail.nih.gov), Dwight Kravitz[2], Chris Baker[1]; [1]Laboratory of Brain and Cognition, National Institute of Mental Health, National Institutes of Health, [2]The Department of Psychology, The George Washington University

Long-term memory processes allow humans to store newly learned information, and recall that information later. Although prior studies have suggested that short-term (or working) memory retrieval generates object-specific representations in visual cortex, it remains unclear how specific the representations recalled from long-term memory are. To test whether the visual cortex as well as hippocampus represents object-specific activation during recall of visual information from long-term memory, we performed an event-related functional magnetic resonance imaging (fMRI) experiment, comprising separate perception, learning and recall sessions. During the perception session, participants were presented with fixed pairings of 14 auditory cues (psuedowords) and object images (e.g. 'tenire'- chair) inside the scanner. During the learning session, on a separate day outside the scanner, participants were trained to memorize the pseudoword-object associations for about one hour. Finally, one day after the learning session, participants were scanned and instructed to recall each object image in response to the paired pseudoword cue. To test the veracity of the recalled visual information, participants were asked to perform forced-choice tests and draw detailed pictures of the object images after the retrieval scan session. Every participant showed good performance in the forced-choice (> 90% correct) and drawing tests. We focused on two primary regions-of-interest: object-selective cortex and hippocampus. Both object-selective cortex and hippocampus were significantly activated during the recall of paired object images. Moreover, the response of both object-selective cortex and hippocampus areas could be used to decode the identity of individual remembered objects, and there was close correspondence between the rep-

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resentations during perception and retrieval in object-selective cortex. These results suggest that recall of visual information from long-term memory activates a fine-grained representation in both hippocampal and cortical areas.

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23.557 Sharp emergence of working memories along the primate dorsal visual pathway

Diego Mendoza-Halliday[1](diego.mendoza@mail.mcgill.ca), Santiago Torres[1], Julio Martinez-Trujillo[1]; [1]Department of Physiology, McGill University

The temporary storage of visual information in the absence of retinal inputs is known as visual working memory. It is long established that in primates, visual working memory representations are encoded in the sustained spiking activity of neurons in high-order cortical areas far downstream along the visual processing pathways, such as the lateral prefrontal cortex (LPFC). Several studies have recently argued that these representations are also encoded in the spiking activity of neurons in early visual cortical areas. Where along the visual stream working memory representations emerge remains highly controversial. Here we show that in macaque monkeys, working memories of visual motion direction are not encoded in the spiking activity of direction-selective neurons in early visual area middle temporal (MT). Surprisingly, these memories robustly emerge immediately downstream, in multimodal association area medial superior temporal (MST). Working memories in MST were as strong as (mean auROC, P = 0.13, t-test) and lasted longer than (% significant bins, P = 0.03, t-test), those found in LPFC. On the other hand, activity during working memory maintenance was more predictive of task performance in lPFC than in MST (mean choice probability, cp = 0.61 in LPFC; cp = 0.55 in MST; P = 0.02, t-test). Our findings reveal a sharp functional boundary between early visual areas, mainly encoding sensory inputs, and downstream association areas, additionally encoding the contents of working memory. Moreover, we found that local field potential oscillations in MT encoded the memorized directions and, in the low frequencies, were phase-coherent with spikes from LPFC neurons in 12.5% (14 of 112) of the recorded LPFC-MT pairs. This suggests that LPFC modulates synaptic activity in MT, a putative top-down mechanism by which working memory signals influence sensory processing in early visual cortex.

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23.558 Right-hemisphere dominance in visual working memory for color-shape binding

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Binding in visual working memory (VWM) remains equivocal whether non-spatial features are bound together, or independently maintained. Evidence for and against binding in VWM show a lack of binding costs during change detection tasks and the independence of color and shape during feature report tasks, both of which are based on null results. The current study obtained evidence for a significant, functional role of binding in VWM by extending the redundancy gain paradigm, which has been used to examine feature coactivation by the race model inequality test. Instead of a predefined set of critical and distractor features, the current study presented a set of critical features as a memory display with two objects within a participant's right and left hemifield, followed by a feature-matching task after a variable interval. Participants remembered critical features and judged if a probe object contained any critical features, regardless of the feature locations. The probe contained two (redundant trials), one (single-feature trials), or zero critical features (new trials). To evaluate the objectness effect, redundant trials were divided into grouped and separated conditions in which color and shape belonged to a single object and two objects in the memory display, respectively. The race model inequality test revealed significant feature coactivation only when features were presented to the left side in the memory display of the grouped condition. The N1 amplitude around centro-parietal electrodes, contralateral to the probe in the grouped condition, was significantly larger than in the separated condition but only for the memory-left trials, consistent with the RT data. Moreover, the hallmark of object files, location-based preview benefit (LSPB), was observed only in the probe-left trials, and ERP at posterior parietal sites during 250–350ms revealed a consistent pattern. Binding VWM is formed even when feature-conjunction is task-irrelevant, but dominated in the right hemisphere.

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23.559 A link between brain structure/connectivity and visual short-term memory capacity

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People can maintain a great deal information in visual sensory memory (VSM) for a brief period of time (Sperling, 1960; Sligte, Scholte, & Lamme, 2008), or just a few objects in visual working memory (VWM) for sustained periods of time (Luck & Vogel, 1997; Vogel, Woodman, & Luck, 2001). In the present study, we investigated whether individual differences in VSM and VWM capacity were reflected in structural brain differences. 950 subjects, representative of the Dutch population between the age of 20 and 25, were recruited from whom we acquired T1, DWI and resting state measurements. Outside of the MRI scanner, participants performed a partial-report change detection task (as in Sligte et al., 2008), where they had to remember eight items over a retention interval of two seconds. A single item was cued immediately after offset of the memory array (measuring iconic memory), one second after memory array offset (measuring fragile memory), or after onset of the test array (measuring working memory). Preliminary results indicate that the global pattern is similar to one of our earlier studies measuring only 52 psychology students. Individual differences in iconic memory and fragile memory capacity are linked with differences in grey matter density in visual cortex. On the other hand, individual differences in visual working memory capacity were related to structural differences in parietal and prefrontal cortex. We are currently analyzing whether the observed patterns are omnipresent or specific for certain subpopulations within our sample. In addition, we are exploring to what degree visual working memory measures correlate with gene group statistics.

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23.560 Probing the neural basis of visual working memory: A validation study using fMRI and fNIRS

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Visual working memory (VWM) plays a key role in visual cognition, comparing percepts and identifying changes in the world as they occur. Previously, fMRI has identified activation in frontal, parietal and temporal areas involved in VWM. Here, we conducted a cross-modal neuroimaging study to determine whether functional near-infrared spectroscopy (fNIRS) was an effective tool to measure changes in activation during VWM processing. We used fNIRS in conjunction with fMRI during an event-related color change detection task with set sizes (SS) 2, 4 and 6. Half of the trials were change trials. Thirteen subjects participated. Positions of sources and detectors were digitized and transformed to a common adult atlas. Monte-Carlo simulations generated probability distributions of photon migration for all channels that were then, transformed to MNI space and combined to create subject-specific masks. The thirteen subject-specific masks were combined to create a union mask. fMRI and fNIRS signals were corrected for motion, de-convolved to create maps of beta coefficients, and weighted by the union mask. Voxel-based correlations were computed between fMRI and fNIRS beta coefficients and analyzed. Stronger hemodynamic activation was reported across frontal, parietal, and temporal regions for SS6 than for SS2 for hits, misses, false alarms and correct rejections. Specifically, strong correlations between fMRI and fNIRS were observed in the intra-parietal sulcus (IPS) for Hits at SS 6 than for SS2. Correct Rejections at SS6 elicited greater activation in the middle frontal gyrus than SS2. Further, IPS also showed greater activation on False Alarms than for Misses, for SS2 and SS6. Robust voxel-based correlations between fNIRS and fMRI signals demonstrated that fNIRS is an effective tool to measure functional activation in the VWM network. This is significant because fNIRS is cheap, portable, and can be used with infants and aging and clinical populations.

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23.561 Using EEG to assess the relationship between load-dependent changes in alpha-band power and visual cortex excitability

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Studies exploring the role of neural oscillations in cognition have revealed sustained increases in alpha-band (~8-14 Hz) power during the delay period of verbal and visual short term memory (STM) tasks. Such increases have been proposed to gate the flow of information from cortical areas representing potentially disruptive, task irrelevant information. In keeping with this possibility, alpha-band increases have been observed over cortical regions representing task-irrelevant properties of remembered stimuli (e.g., over the dorsal stream during the retention of face-identity vs. face-orientation information; Jokisch & Jensen, 2007). However, similar increases have also been observed when all remembered stimulus features are task relevant, and therefore inhibitory gating would presumably not be required (Johnson, et al. 2011). This suggests that alpha-band oscillations may play a role in the active retention of information in STM. In the present study, we explore a third possibility: that alpha-band oscillations reflect the gating of incoming sensory inputs, even when no task-irrelevant information is being retained. To test this possibility, we recorded the electroencephalogram (EEG) while subjects performed a change detection task that required the retention of varying numbers of colored squares on each trial. Importantly, on a portion of trials, a series of task-irrelevant checkerboard probes were presented bilaterally to assess the excitability of visual cortex. We reasoned that, if load-dependent alpha-band power increases represent the gating of sensory inputs, they should be associated with modulations of components of the visual evoked potential (VEP) on a subject-by-subject basis. Although we did observe group level load-dependent increases in the magnitude of the N1 VEP and in delay-period alpha-band power, these changes were not correlated at the individual subject level. We conclude that load-dependent changes in alpha-band power are not associated with the gating of task-irrelevant sensory inputs in the standard change detection task with bilateral stimulus presentation.

Object recognition: Reading

Saturday, May 17, 8:30 am - 12:30 pm
Poster Session, Pavilion

23.562 The remarkably fast temporal resolution of feature integration in letter perception

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Visual word recognition is a remarkably fast process; recent studies have demonstrated a 100ms temporal resolution for letter binding. Such studies used an RSVP paradigm wherein a word's component letters are temporally separated along a presentation stream of varying SOAs (e.g., H_M_, _O_E, for HOME); the parts integrated into a unitary percept when SOAs were less than 100ms. Importantly, just as letters must integrate to support whole-word recognition, features must also integrate to support letter identification. The current study used a modification of the RSVP paradigm to assess the temporal resolution of feature integration in letter perception. Specifically, we introduced noise letters into the presentation stream which fused with the target letters when SOAs were faster than 36ms. In the first experiment, we manipulated the distribution of the target letters along the presentation stream. Target and noise letters were presented separately, (e.g., HOME, XXXX) or together (e.g., HXMX, XOXE). When SOAs were less than 36ms, feature fusion across presentations caused the two conditions to look identical. When SOAs exceeded 36ms, feature fusion was no longer possible, and accuracy was higher when the target and noise letters were presented separately. In the second experiment, we manipulated the composition of the noise letters; the target letters were presented alongside several noise letters (e.g., HXVY, ZOTE) or alongside a single, repeated noise letter (e.g., HXMX, XOXE). When SOAs were less than 36ms, accuracy was higher in the several-noise condition; temporal fusion caused the features of the different noise letters to average out. When SOAs exceeded 36ms, accuracy was higher in the single-noise condition; features no longer fused across presentations and the target letters benefited from a pop-out effect. Together, the results from both experiments converge on a 36ms temporal resolution for feature fusion in letter identification.

23.563 Individual differences in visual lexical decision are highly correlated with orientation tuning

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Recent research has brought attention to the importance of the orientation tuning of visual information. For instance, in face recognition, participants show higher efficiency for horizontal information (e.g. Pachai, Sekuler & Bennett, 2013). Here, we investigated whether this also applies to visual word recognition. Fifteen participants performed a lexical decision task. Each trial began with a fixation cross displayed for 500ms, immediately followed by a stimulus (about 2 degrees of visual angle) that remained on screen until response. The stimuli consisted of 300 high lexical frequency five-letter French words and 300 pseudo-words, which we generated by replacing one letter in each word (either the second, third, or fourth). Fast Fourier Transforms of stimuli were performed to preserve only vertical or horizontal information. Gaussian white noise was added to the reconstructed output to maintain performance at 75% in each condition. The threshold was estimated using QUEST (Watson & Pelli, 1983). Efficiency was calculated for each condition by comparing human performance with that of an ideal (template-matching) observer. Both the human and the ideal observers needed less signal for vertical compared to horizontal information. However, the ideal to human ratios show that, at the group level, experienced readers have similar efficiency for both orientations, (Mvertical= .0112, Mhorizontal= .0113, $t(14)= -.09$, ns). To better characterize orientation tuning, we correlated efficiency with reading speed; this was measured in another lexical decision task using 100 unaltered stimuli (50 words). Interestingly, we found that reaction times are strongly correlated with the difference between horizontal and vertical efficiency ($r= -.6$, $p<.05$). Our results suggest that faster readers perform better with horizontal than vertical information, while the reverse holds for slower readers. Further investigation on the issue should examine the possible link between individual differences and sensitivity to crowding, as vertical information appears to constrain its spread.

23.564 An optimal viewing position for object processing

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The ease with which a written word is processed depends on where the eyes initially fixate it. The optimal viewing position (OVP) is at the center of words, or slightly to the left of it. When the eyes initially fixate on this position, as compared to on a word's extremes, words are identified faster and more accurately, and are less likely to be refixated (OVP effects), whereas initial-fixation durations are longer (the inverted-OVP effect). These effects are typically explained as a combination of a central bias, due to the rapid drop-off of visual acuity from the center of the fovea, and a slightly-leftward bias, due to language-related constraints. We investigated whether these biases also characterize object processing. Although several studies indeed suggest there is a central OVP for objects, previous results are equivocal. Therefore, we examined whether (inverted) OVP effects exist for object processing, and if so, to what extent they differ from the ones typically observed for word processing. We carried out an object- versus word-naming task, and manipulated the location of the stimulus relative to a previously-displayed fixation dot. As a consequence, participants initially fixated different parts of the stimulus. To facilitate comparison between the two stimulus types, line drawings were scaled such that their width matched the width of the corresponding written word. We found that participants made less refixations, and showed longer initial-fixation durations, when their eyes initially fixated at the center, regardless of stimulus type. This confirms that both word- and object-processing are more efficient when the location of the eyes allows maximal visual-information uptake. However, both effects were weaker for pictures than for words. Furthermore, within-stimulus refixations showed a larger leftwards bias in words than in objects, suggesting additional language-related constraints for word processing. We will also discuss alternative, visual explanations.

23.565 Context effects in reading depend on reading speed and print size

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Introduction: Sentences are generally read faster than random sequences of words, presumably because the sentence context reduces uncertainty in identifying upcoming words. Does this context advantage extend to reading small print? Small print is hard to read. Context could help reduce uncertainty in hard-to-read words, but if the words are hard to read it may be difficult to establish the context in the first place. Methods: We collected psychometric functions measuring reading accuracy as a function of print size (−0.3 to +0.4 logMAR) for normal and shuffled sentences. The sentences had either 6 or 10 words and were displayed at RSVP presentation rates of 60, 120, 190, 337, and 600 wpm. Data were collected from two well-practiced observers with normal vision. Results: For faster presentation rates, accurate reading requires larger print sizes and there is a marked difference between reading normal and shuffled sentences (e.g., with presentation rates just slower than the maximum reading speed for shuffled sentences, print sizes for 80%-correct reading are 0.15 log units larger for shuffled than for normal sentences.) For slower presentation rates, reading can be performed at smaller print sizes; however the difference between normal and shuffled sentences diminishes. Surprisingly, for speeds ≤120 wpm, context has no effect at all — the psychometric functions for normal and

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shuffled sentences are identical. Conclusions: These findings show that the relationship between reading speed, print size, and sentence context is complex. Fast reading with large print sizes is clearly helped by context. But for slow reading near the acuity limit, context cues are unavailable, unhelpful, or unused. This underlines the importance of using continuous text on tests of visual function for reading with large print, but suggests that random words may be sufficient for tests of reading at the acuity limit.

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23.566 **Word-length Effects and Word Inversion Effects: A Study of Perceptual Transforms in the Reading of Single Words** Laura Eklinder Björnstrom[1,2](lauek181@student.liu.se), Charlotte Hills[1], Hashim Hanif[1], Jason Barton[1]; [1]Department of Medicine (Neurology), Department of Ophthalmology and Visual Sciences University of British Columbia, Canada, [2]Faculty of Medicine, Linköping University, Sweden

Background: Reading may be processed at either the level of the whole word or its individual letters, and the word-length effect may provide an index of serial letter processing versus rapid parallel or holistic processing. How reading is performed under various perceptual transforms and whether a word inversion effect is specific for normal text (as predicted by the expertise hypothesis) is not clear. Objective: We measured the word length effect in normal text or two transformations, mirror reflection (in which the form of the whole word is preserved) or written backwards, in both upright and inverted orientation. Methods: We measured verbal response time of 12 healthy subjects reading 3- to 9-letter words presented one at a time in random order, with transformations and orientations in different, counterbalanced blocks. Results: There was a main effect of transformation ($F(2,55) = 39.52$, $p < .0001$), with Tukey's HSD test now showing differences between all three transformations. Mirror text had a larger word-length effect than either backwards text ($F(1,55) = 6.56$, $p < .003$) or normal text ($F(1,55) = 9.68$, $p < .003$), while backwards text also had a larger word-length effect than normal text ($F(1,55) = 9.68$, $p < .003$). There was a trend to an interaction between orientation and transformation ($F(2,55) = 2.77$, $p < 0.07$). Tukey's HSD test showed that the inversion effect was significant for normal text ($F(1,55) = 9.68$, $p < .003$), but not for mirror or backward transformed text. Conclusion: Reading of perceptually difficult transformed text uses primarily local letter processing, consistent with predictions that rapid parallel or holistic word processing is acquired through experience and therefore limited to familiar text formats. The inversion effect suggests that the word-length effect is a more effective index of this expert process than mean response time. Funding: Canada Research Chair and Marianne Koerner Chair in Brain Diseases (JB)

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23.567 **Learning to read upside-down: a study of perceptual expertise and acquisition** Cristina Rubino[1], Elsa Ahlen[2], Charlotte S. Hills[1], Hashim M. Hanif[1], Jason J. S. Barton[1]; [1]Departments of Medicine (Neurology), Ophthalmology and Visual Sciences, Psychology, University of British Columbia, [2]Faculty of Medicine, University of Linköping

Introduction: Reading is an expert visual and ocular motor function, learned almost exclusively in a single orientation. Characterizing this expertise can be accomplished by contrasts between reading of normal and inverted text, in which perceptual but not linguistic factors are altered. Objective: Our goal was to examine this inversion effect in healthy subjects reading text, to derive behavioural and ocular motor markers of perceptual reading expertise, and to study these parameters before and after training with inverted reading. Methods: Seven subjects underwent a 10-week program of 30 half-hour sessions of reading novels with pages displayed inverted on computer monitors. Before and after training we assessed reading of upright and inverted single words for response time and word-length effects, and reading of paragraphs for time required, accuracy, and ocular motor parameters. Results: Subjects gained about 1.17 words/minute with each session, or a substantial 35 words/minute over the entire training period. Before training, inverted reading was characterized by long reading times and large word-length effects, with eye movements showing more and longer fixations, more and smaller forward saccades, and more regressive saccades. Training partially reversed many of these effects in single word and text reading, with the best gains occurring in reading aloud time and proportion of regressive saccades, and the least change in forward saccade amplitude. Conclusions: Reading speed and ocular motor parameters can serve as markers of perceptual expertise during reading, and that training with inverted text over 10 weeks results in gains of about 30% in reading expertise. This approach may be useful in the rehabilitation of patients with hemianopic dyslexia, as inverted reading has the potential of restoring parafoveal preview and visual span in front of the currently fixated letter.

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23.568 **Processing of words and text in prosopagnosia** Charlotte Hills[1](hvem@eyecarecentre.org), Cristina Rubino[1], Claire Sheldon[1], Raika Pancaroglu[1], Jodie Davies-Thompson[1], Jason Barton[1]; [1]Department of Medicine (Neurology), Department of Ophthalmology and Visual Sciences, University of British Columbia

Background: Words and faces are both subjects of highly expert perceptual processing, but there is a left hemisphere dominance for reading and a right one for face perception. Nevertheless, both have some bilateral representation, raising the question of whether there is some mild word processing impairment in patients with prosopagnosia. Objective: We examined whether patients with prosopagnosia from right hemisphere or bilateral lesions were also impaired in text style discrimination, or word perception. Markers used were delayed word matching and an exaggerated word-length effect, where reading time is proportional to the number of letters in a word. Method: 9 prosopagnosic subjects participated. In the first experiment, subjects sorted handwritten and typed words by either their meaning or their style (i.e. handwriting or font), with the time taken and accuracy measured. In the second experiment we measured the word-length effect for reading single words of 3 to 9 letters, matched for linguistic frequency. The time to onset of verbal naming response was recorded. Results: In experiment 1, no subject demonstrated delayed or inaccurate sorting of words by their identity. Of 4 subjects with only right hemisphere lesions, 3 were impaired in matching for style matching, as were all of the 5 subjects with bilateral lesions. In experiment 2, no subjects with right hemisphere lesions alone showed an exaggerated word-length effect, while all but one of those who had additional left sided damage did. Conclusion: These findings provide further evidence that right hemisphere lesions impair processing of stylistic properties of text. Reductions in the efficiency of word processing appear to require additional left sided lesions in prosopagnosic patients.

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23.569 **Symbolic object representation in visual cortex** Jodie Davies-Thompson[1,2](jdthompson@eyecarecentre.org), Taim Muayqil[1,2], Jason JS Barton[1,2]; [1]Department of Medicine (Neurology), University of British Columbia, [2]Department of Ophthalmology and Visual Sciences, University of British Columbia

Background: Previous studies have shown that word processing involves a predominantly left-sided occipitotemporal network. Words are a form of symbolic representation, in that they are arbitrary perceptual stimuli that represent other objects or concepts. Patients with alexia can have problems processing other types of symbols, such as musical notation. Whether other symbolic visual representations are processed similarly to visual words is not known. Objective: We determined whether there were any occipitotemporal regions that showed an overlap in processing a number of different visual symbolic classes. Method: 16 right-handed music-literate subjects took part in an fMRI study designed to examine the response in occipitotemporal cortex to other forms of symbolic representations. We examined four symbolic categories: a) words, b) musical symbols, c) traffic symbols, and d) flags and logos. BOLD signal during perception of these categories was contrasted with activity related to 1) their spatially scrambled equivalents, and 2) pseudo-symbolic equivalents, which were similar stimuli that lacked symbolic context. Results: The right and left VWFA responded to words, musical annotations, and traffic symbols; however, these areas also responded to pseudo-symbolic equivalents. Rather, greater response to symbolic than pseudo-symbolic stimuli was seen in the left inferior temporal gyrus (ITG) and middle temporal gyrus (MTG). A whole brain analysis comparing the response to symbolic versus pseudo-symbolic stimuli revealed a distributed network of inferior temporooccipital and parietal regions responding to the different categories. Conclusion: The regions involved in processing visual words, including the VWFA, the left ITG, and left MTG, also play a role in processing not just words but also some forms of symbolic representations, particularly musical notation.

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23.570 **Representation of word identity and font in visual cortex**

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Reading involves the recognition of words on the basis of shape information; different words are specified by different strings of letter shapes. Reading also involves the recognition of a word presented in different fonts; word identity is invariant to font changes. We used fMRI to study the neural responses to changes in word identity and font in visual cortex. We measured fMRI responses to four-letter words which either changed or repeated in the following ways: (1) the same word was repeated in the same font; (2) the same word was repeated in different fonts; (3) different words were presented in different fonts. We also employed two additional conditions in which either the right or left half of words changed while the other half remained the same (words were split at fixation), which allowed us to dissociate the effects of hemifield-specific letter identity and font changes between the two hemispheres. Our primary finding was that changes in identity resulted in left lateralized fMRI responses in visual cortex, most notably in an area of occipitotemporal cortex corresponding to the visual word form area (VWFA), but also in more posterior portions of visual cortex. In contrast, fMRI responses to font changes in the absence of identity changes were not lateralized, but nevertheless overlapped highly with the left lateralized fMRI responses observed in our other conditions. Our results support the view that both visual cortical hemispheres represent shape information during word recognition and that the left occipitotemporal cortex represents word identity.

23.571 **Orthographic and lexical sensitivity to words in the ventral occipitotemporal cortex** Qiujie Weng[1](wengx022@umn.edu), Hao Zhou[2], Lan Wang[2], Sheng He[1]; [1]Department of Psychology, University of Minnesota, [2]State Key Laboratory of Brain and Cognitive Science, Institute of Biophysics, Chinese Academy of Sciences

Previous studies have identified a number of word-sensitive regions in the ventral occipitotemporal cortex. In this study, we used fMRI adaptation and multi-voxel pattern analysis to investigate their functional properties such as orthographic and lexical sensitivity. Three categories of Chinese character-related stimuli were adopted - real characters, pseudo characters, and false characters. They were structurally matched but differed in their lexical and orthographic properties. Real characters were common left-right structured characters. A pseudo character was created with two parts according to the orthographic rule. A false character was also formed of two parts but they occupied incorrect positions thus breaking the orthographic rule. During the fMRI adaptation experiment, target probes from one category were briefly presented amidst prolonged exposure to adaptors from either the same or different category of stimuli. Comparing the within-category and between-category adaptation effect for a region could reveal its orthographic and lexical sensitivity. Three word-sensitive regions were functionally localized, one in the occipital lobe, another near the occipitotemporal sulcus (i.e., the VWFA), and the third located further anterior to the VWFA. fMRI adaptation results show that real and pseudo characters were differentiated in the VWFA and the more anterior ROI, since they had greater within-category adaptation effect than cross-category adaptation effect. However, adaptation to false characters was less category selective, possibly reflecting that the ROIs under consideration were less sharply tuned to the false characters. Within these ROIs, information carried in the multi-voxel pattern of response could support successful classification of all three types of characters. Interestingly, adaptation to real characters significantly reduced the correlation-based classification performance in the VWFA and the more anterior ROI. Thus, while the orthographic information is likely registered earlier in the pathway, the lexical difference between real and pseudo characters are represented once the information reaches the VWFA and thereafter.

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23.572 **Neural correlates of font sensitivity effects in the perception of simplified and traditional Chinese characters** Tianyin Liu[1](kanalty@hku.hk), Janet Hui-wen Hsiao[1]; [1]Department of Psychology, The University of Hong Kong

Changes in font regularity within a word or between words are shown to affect experts more than novices in visual word recognition (Gauthier et al., 2006). Consistent with this finding, we recently found that expert Chinese readers showed stronger left side bias (i.e., the preference to judge a character made from two left-halves of a mirror-symmetric character more similar to the original character than one from two right-halves; Hsiao & Cottrell, 2009) in perceiving characters in a familiar font than in an unfamiliar font. Nevertheless, this font sensitivity effect was limited to characters with the visual complexity of the script that the readers were most familiar with. Here we used a masked repetition priming paradigm in a semantic decision task with EEG recording to examine font sensitivity effects in simplified and traditional Chinese readers with simplified, traditional, and shared (shared between the two scripts) character stimuli. In each trial, the target character was presented in a familiar font (song), while the prime was in either the same (song) or a different, unfamiliar font (feng). Since simplified script readers are not familiar with traditional characters, they may demonstrate less font sensitivity to traditional characters. In contrast, because the visual complexity of shared characters are similar to simplified but not traditional characters, font sensitivity effects may only be observed in traditional characters among traditional Chinese readers. Consistent with our hypothesis, the font change across the prime and target affected N1 amplitude among simplified Chinese readers when perceiving simplified and shared but not traditional characters. In contrast, traditional Chinese readers demonstrated a marginal font sensitivity effect only in traditional characters. These results suggest that font sensitivity depends on experience with the visual complexity of the script. The heterogeneity in visual complexity among Chinese characters provides this unique opportunity to reveal this effect.

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23.574 **Writing reduces holistic processing but does not facilitate reading: The case in Chinese children with developmental dyslexia.** Ricky Van-yip Tso[1](richie13@hku.hk), Cecilia Nga-wing Leung[1], Terry Kit-fong Au[1], Janet Hui-wen Hsiao[1]; [1]Department of Psychology, The University of Hong Kong

Holistic processing (HP) is an expertise marker of face and object recognition. By contrast, the expertise marker of recognizing Chinese characters is reduced HP (Hsiao & Cottrell, 2009). Such reduction in HP seems to be driven mainly by writing experience rather than reading ability (Tso, Au, & Hsiao, 2013). In addition, HP seems to mediate between writing and reading in elementary-school children learning to read and write Chinese (Tso, Au & Hsiao, 2012): writing experience enhances analytic processing and awareness of orthographic components of Chinese characters, which in turn facilitates reading in Chinese. Here we examined this HP effect—i.e. reduced HP as an expertise marker—of Chinese character recognition in dyslexic and typically developing children (using the complete composite paradigm; Gauthier & Bukach, 2007) and its relationship with other Chinese proficiency measures (using age-matched, IQ-matched and performance-matched research design). We found that when the HP effect was matched between the two groups, they did not differ significantly in word dictation performance, and vice versa. This suggests that HP and writing performance in Chinese characters are associated, consistent with Tso and colleague's (2012, 2013) finding that reduced HP of Chinese characters may result from writing rather than reading experience. By contrast, even with HP or dictation performance matched, dyslexic children were outperformed by typically-developing children in Chinese character naming, revealing little association between HP/writing and reading of Chinese characters. The importance of writing experience for reading Chinese in typical developing children (e.g., Tan et al., 2005; Tso, Au & Hsiao, 2012) notwithstanding, our results suggest that the fundamental difference in reading performance between Chinese typically developing and dyslexic children cannot be accounted for by HP or writing performances. Dyslexic children's failure in recognizing Chinese characters may result from deficits in other types of processes than perceptual deficits or writing abnormality.

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23.575 **Development and Validation of a Chinese Reading Acuity Chart** Lin-Juan Cong[1](conglinjuan@gmail.com), Cong Yu[2], Lei Liu[3]; [1]School of Brain and Cognitive Science, Beijing Normal University, [2]Department of Psychology and Peking-Tsinghua Center for Life Sciences, Peking University, [3]School of Optometry, University of Alabama at Birmingham

The MNREAD chart is widely used in scientific research and clinical assessment for English readers. In this study we developed and validated a set of Chinese reading acuity chart using simplified Chinese characters using the similar design principles of MNREAD. 105 simple declarative sentences (subject-verb-object), 12 characters each, were initially selected from 1st- to 3rd-grade textbooks in elementary schools in China. 67 were selected after eliminating those with too many or too few total number of strokes. Reading speeds and errors were estimated with 20 Chinese college students, along with subjective ratings on contents and fluency. 48 sentences were finally selected based on the uniformity in

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reading speeds and subjective ratings and were used to make 3 reading charts. Each logarithmic chart contained 16 sentences, one sentence per line, covering the acuity range from 20/320 to 20/10 at a 40-cm reading distance. The mean numbers of strokes per sentence for the three charts were 87.2±3.5, 87.4±3.3 and 87.3±3.4. Thirty young, normally-sighted college students were tested with two randomly selected charts and were scored using the MNREAD protocol. They also read two 150-character continuous texts at middle-school level at a 0.7 logMAR print size. The mean reading acuity (rac), critical print size (cps) and maximal reading speed (mrs) were 0.20 logMAR, 0.40 logMAR and 284 char/min, respectively. There were no significant differences in rac, cps and mrs among the 3 charts (p=0.29, 0.63 & 0.82, respectively), and between the readings of two randomly selected charts (p=0.47, 0.34 & 0.23, respectively). The test/retest reliabilities (r/rho) were 0.59, 0.34 and 0.91 for rac, cps and mrs. The maximal reading speed was correlated to that of continuous text (r=0.83, p<0.001). The new Chinese reading acuity charts exhibit the characteristics of an accurate and reliable functional reading assessment instrument.

23.576 **An Art Meets Science: Subtle Typeface Design Characteristics Affect Word Legibility in Brief Glances** Jonathan Dobres[1](jdobres@mit.edu), Nadine Chahine[2], Bryan Reimer[1], David Gould[2], Bruce Mehler[1], Brahmi Pugh[1], Stephen Arredondo[1]; [1]AgeLab, Engineering Systems Division, Massachusetts Institute of Technology, [2]Monotype Imaging, Woburn, MA

Typeface design has long been considered an art, one guided by a long accumulation of best practices. Differences between typefaces can be obvious, such as the flourishes of a serif typeface versus the clean outlines of sans-serifs, or they may be minor, such as the variability of stroke width within a letter. Here we employ psychophysical techniques to investigate the legibility of two seemingly similar typefaces, a “humanist” style typeface and a “square grotesque”. Subjects participated in a yes/no (2AFC) task in which they determined whether a briefly presented stimulus was a word or a pseudoword (a combination of letters that is not an English word, but is pronounceable). Each subject was exposed to four conditions: two typefaces by two color combinations (black text on a white background or vice versa). All text was shown using the computer operating system’s standard text rendering algorithm. Stimulus presentation time was controlled via a 2-down, 1-up adaptive staircase procedure, and presentation time thresholds were calculated separately for the four combinations of typeface and color. Results indicate that presentation thresholds are significantly lower for the humanist typeface compared to the square grotesque, and are also lower for the black on white conditions compared to white on black. The typefaces chosen are both sans-serif with similar stroke widths, and were adjusted to equalize their optical heights. However, our results show that the deeper design characteristics of a typeface can substantially affect its legibility. We speculate that the more open and varied letterforms of the humanist typeface may reduce visual crowding, making it superior to the more uniform and ambiguous letterforms of the square grotesque. Whether the legibility advantage of black on white text arises from subtle optimizations in the text rendering algorithm or has a neurological basis is an open question.

Acknowledgement: Monotype Imaging US Dept. of Transportation

Object recognition: Categories

Saturday, May 17, 8:30 am - 12:30 pm
Poster Session, Pavilion

23.577 **Exploring the representational geometry of object representation in the ventral stream using brain-behavior correlations**
Michael A. Cohen[1](michaelthecohen@gmail.com), Talia Konkle[1], Ken Nakayama[1], George A. Alvarez[1]; [1]Department of Psychology, Harvard University

The visual processing stream contains regions that selectively respond to different objects, and the representational geometry within each region can be measured by the similarity of responses across different items (Kriegeskorte et al., 2008). Here we asked if interference between objects in a perceptual task is predicted by the representational geometry across different regions of the visual system. To measure perceptual interference, sixteen participants performed a visual search task with eight categories: faces/bodies/buildings/cats/cars/chairs/hammers/phones. On target present trials, one target was shown amongst seven distractors from one category (e.g. one face/seven chairs), and reaction time was measured for each target-distractor pairing. Reaction times were used as an index of perceptual similarity between categories, yielding an 8x8 behavioral-similarity matrix. To measure the representational geometry of different visual areas, six new participants were scanned using fMRI while viewing individual items from each category. The neural patterns for each category were correlated with one another across several cortical regions, yielding an 8x8 neural-similarity matrix for each region. Do these neural-similarity measures correlate with the behavioral-similarity measures? We found strong correlations across the ventral/dorsal pathways (ventral temporal, r=0.79; lateral temporal, r=0.62; occipitoparietal, r=0.54), but not V1-V3 (r=0.13). To test the uniformity of this representational geometry, lateral temporal, ventral temporal, occipitoparietal, and V1-V3 were divided into ten ROIs based on overall voxel activity. Surprisingly, the correlations in each sub-region remained high throughout ventral- and lateral-temporal cortex (all sub-regions P<0.05). Furthermore, we found significant correlations within both FFA (r=0.66) and PPA (r=0.66). These results suggest that the representational geometry in higher-level visual areas constrains object perception and is highly uniform across ventral visual cortex. The uniformity of this representational geometry, despite differences in response selectivity, suggests that different regions of ventral visual cortex extract, and make explicit, different subsets of highly correlated perceptual features.

23.578 **Emergence of orientation invariant representations within the visual cortex** Morgan Henry[1](morganhenry@college.harvard.edu), George A. Alvarez[1]; [1]Department of Psychology, Harvard University

It’s surprisingly easy to recognize objects at different sizes, orientations, and positions in the visual field. Robust object recognition across such transformations suggests that the visual system achieves an (almost) invariant representation at some level. While understanding the computations that underlie view-invariant representation is an ongoing topic of research (DiCarlo & Cox, 2007), it remains unclear exactly where and how invariance is achieved. Here, we aim to provide some insight into this question by exploring the emergence of orientation invariant representations within the visual system using fMRI. We used a rapid-event related paradigm in order to attain highly reliable brain patterns for 40 items (8 distinct objects at 5 orientations each; average reliability across items and subjects, r=.79). We then divided the cortex into several regions of interest, including V1-V3, lateral occipital complex (LOC), and the broader occipitotemporal cortex (OTC). We divided the data set into all possible halves of the 12 runs, and computed the correlation between item patterns for each half for all combinations of the 40 items (1600 correlations). This analysis revealed strong orientation dependence in V1-V3: for a given object, pattern similarity decreased as the difference in orientation between items increased. In contrast, LOC showed evidence for complete invariance: the average pattern for a particular object on one half of runs (e.g., upright face) was just as similar to the same object at the same orientation (upright face) as it was to the same object at any other orientation (45, 90, 135, 180 deg) on the other half of runs. The same degree of orientation invariance was observed in OTC. These results show that object responses in occipitotemporal cortex are completely invariant, not just tolerant, to changes in orientation, and suggest that these invariant representations emerge abruptly in the transition between early visual cortex and LOC.

Acknowledgement: Harvard Center for Brain Science Thesis Award to M.H.

23.579 **Differential rate of temporal processing across category-selective regions in human high-level visual cortex** Anthony Stigliani[1](astiglia@stanford.edu), Kevin S. Weiner[1], Kalanit Grill-Spector[1,2]; [1]Department of Psychology, Stanford University, [2]Stanford Neuroscience Institute, Stanford University

What is the speed of processing in high-level visual cortex? Previous research (McKeeff et al. 2007) suggests that responses in human face- and scene-selective regions peak for stimuli presented at 4-5 Hz, unlike early visual areas that respond maximally for faster rates of presentation (18-25 Hz). However, these results are hard to interpret because presentation rate and the number of images in a block were confounded. Here, we used a novel paradigm to measure the rate of processing across human high-level category-selective regions. Twelve participants were scanned with fMRI while viewing images of faces, bodies, objects, scenes, and written characters presented at 1, 2, 4, or 8 Hz. Stimuli were presented in 8-image blocks at all rates to equalize the number of stimuli in a block across rates. Results indicate that networks of category-selective regions are optimized to process stimuli at different rates, with regions selective for faces, scenes, and characters preferring slower rates (2 Hz), and body-selective regions preferring faster rates (4 & 8 Hz). This pattern of results manifests in three ways: (i) The proportion of VTC voxels showing selectivity for a category peaked at a certain rate. Specifically, the proportion of VTC voxels selective for faces, scenes, and characters was greatest at 2 Hz, and the proportion selective for body parts was greatest at 4 Hz (Figure 1). (ii) Independent ROI analyses revealed that selectivity for the preferred category was highest at the optimal rate associated with a region. (iii) Heightened selectivity resulted from a specific increase in the magnitude of response to a region's preferred category at the optimal rate. These results demonstrate differential temporal processing of category information across high-level visual cortex and that bodies are processed at faster rates than other types of stimuli, perhaps as a result of their mobility and non-rigid nature.

Acknowledgement: Research supported by NIH 1 RO1 EY 02231801A1 to K. Grill-Spector

23.580 **Real-world size improves object recognition in visual form agnosia** Jacqueline Snow[1](jacqueline.c.snow@gmail.com), Taylor Coleman[1], Melvyn Goodale[2]; [1]Department of Psychology, University of Nevada, Reno, Nevada, USA, [2]The Brain and Mind Institute, The University of Western Ontario, London, Ontario, Canada

Patients with visual form agnosia have difficulty recognizing pictures of objects but can show improved recognition for real-world exemplars – a phenomenon known as the 'Real Object Advantage'. For most everyday objects, visual size corresponds to real-world size, whereas in standard pictorial tests of object recognition stimuli can often be orders of magnitude smaller than their real-world size. Here we investigated the influence of real-world size on visual object recognition in a patient with visual form agnosia (DF). Recognition performance and response times were measured for real objects that were either 'real size' (e.g., banana) or 'toy size' (e.g., minature aeroplane). Because DF can utilize color and surface texture cues to facilitate recognition, all stimuli in the current study were painted white and had little visible surface texture. We compared DF's recognition performance in a number of different viewing conditions: monocular vs. binocular viewing, and free vs. fixed head position. We also examined DF's ability to recognize photographs of the same set of objects (under binocular free viewing) which were closely matched to the real objects for visual size, viewpoint, and illumination. DF's recognition performance in all viewing conditions (except monocular with fixed head position) was better for real 3D objects than for 2D pictures, and she showed small qualitative improvements in recognition performance for binocular over monocular viewing and with free-viewing over fixed head position. DF's recognition accuracy was strongly influenced by real-world size, with better recognition performance for real-world than toy-sized exemplars. Agnosia patients rely largely upon 'top-down' predictions about object identity based on the size of an object, whereas 'bottom-up' visual shape cues provide secondary information about identity.

23.581 **fMRI activation and connectivity in the dorsal and ventral visual streams for elongated and stubby tools and non-tools** Juan Chen[1](jchen737@uwo.ca), Melvyn Alan Goodale[1], Jody C Culham[1], Jacqueline C Snow[2]; [1]The Brain and Mind Institute, The University of Western Ontario, London, Ontario, Canada, [2]Department of Psychology, University of Nevada, Reno, Nevada, USA

Images of tools induce stronger activation than images of non-tool objects in a left-lateralized network of areas including the superior parietal lobe (SPL) and posterior medial temporal gyrus (pMTG). Importantly, however, graspable tools tend to be elongated rather than stubby, and so the tool-selective responses in these areas may reflect sensitivity to elongation rather than 'toolness' per se. It is also unclear what the role of object identity information from lateral occipital complex (LOC) is in driving responses in dorsal 'tool' regions, such as SPL. Here we performed an fMRI study examining the extent to which 'tool-selective' areas are sensitive to the following object categories: elongated tools, elongated non-tools, stubby tools, and stubby non-tools. We used psychophysiological interactions (PPI) to measure the pattern of connectivity with dorsal tool-selective SPL during the perception of each of the different stimulus types. We observed greater activation for tool versus non-tool stimuli in the left SPL and left pMTG. The tool-selective fMRI responses in both of these areas were driven primarily by elongated rather than stubby exemplars. PPI analyses revealed a stronger connectivity between left SPL and left LOC when observers viewed stubby tools than stubby non-tools. But for elongated tool and elongated non-tools, the connectivity between left SPL and left LOC was not significantly different. Taken together, our results suggest that the SPL and pMTG are particularly sensitive to elongated tools, perhaps because of the statistical regularity of this aspect ratio within the category of tool-like objects. SPL is functionally integrated with ventrally-located object-selective cortex (LOC) during stubby tool viewing, suggesting that dorsal tool-selective areas may rely upon object information from LOC to facilitate action-related processes with stubby tools, but less so for prototypical (elongated) tool exemplars.

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23.582 **Concept Formation and Categorization of Complex, Asymmetric and Impossible Figures** Sarah Shuwairi[1, 2](sms425@nyu.edu), Rebecca Bainbridge[2], Gregory Murphy[2]; [1]Haverford College, Department of Psychology, [2]NYU, Department of Psychology

Impossible figures are striking examples of inconsistency between global and local perceptual structure (see Figure 1a). These images tend to attract our attention and interest for extended periods of time as we try to resolve the component parts, perhaps because each part of an impossible figure in isolation is locally possible, but the overall spatial configuration does not yield a globally coherent 3D object. In order to investigate whether structural "impossibility" was considered an important perceptual property of depicted objects, we used a category formation task in which subjects were asked to divide pictures of shapes into groups that seemed most natural to them. Category formation is usually unidimensional, i.e., sorting is dominated by a single perceptual property, and so it serves as a measure of which features or dimensions are most salient. In Experiment 1, subjects received a set of 12 line drawings, half of which depicted possible and half impossible objects (Figure 1a). Very few subjects grouped the figures by impossibility on the first try, and only half did so after multiple attempts at sorting. Experiment 2 investigated other global properties of figures, such as symmetry and complexity (Figure 1b and 1c). Subjects readily sorted objects by complexity, but seldom by symmetry. In Experiment 3, subjects were asked to draw each of the figures before sorting them, which had only a minimal effect on facilitating categorization. Finally, in Experiment 4, subjects were explicitly instructed to divide the shapes by symmetry or impossibility. Following the prompt, performance on the categorization task was perfect for symmetry, but not for impossibility. Although global properties of figures seem extremely important to our perception, the results suggest that some of these cues are not salient for about half of observers.

Acknowledgement: This research was supported in part by NSF grant BCS-1128769.

23.583 **Comparison of Object Recognition Behavior in Human and Monkey** Rishi Rajalingham[1](rishi.rajalingham@gmail.com), Kailyn Schmidt[2], James J. DiCarlo[1,2]; [1]Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, [2]McGovern Institute for Brain Research, Massachusetts Institute of Technology

While the rhesus monkey is widely used as an animal model of human visual processing, it is not known if high-level visual behaviors, such as invariant object recognition, are quantitatively comparable across rhesus monkeys and human. To address this question, we systematically compared the object recognition behavior of two monkeys (M, Z) with that of human subjects. To enforce true object recognition behavior (rather than image matching), several thousand naturalistic images, each with one foreground object, were generated by rendering a 3D model of each object with randomly-chosen viewing parameters (2D position, 3D rotation and viewing distance) and placing that foreground object view onto a randomly-chosen, natural image background. Monkeys were trained on a match-to-sample paradigm, with 100ms foveal presentation of a sample image (randomly-chosen among thousands possible) followed immediately by lateral presentation of two response images, each displaying a single canonical-view object. Monkey M responded by holding gaze fixation over the selected image for 700ms, while monkey Z touched the selected image on a touchscreen. Data from 554 human subjects performing the same tasks on Mechanical Turk were aggregated to characterize mean human object recognition behavior, as well as 25 separate MTurk subjects to characterize individual human subject behavior. To date, we have compared monkeys and humans on 16 objects. Our results show that monkeys not only match human performance, but show a pattern of object confusion that is highly correlated with pooled human subject confusion patterns (M: 0.8550; Z: 0.8148; noise corrected r), and is statistically indistinguishable from individual human subjects (p=0.48, exact test). Importantly, these common patterns of 3D object confusion are not shared with low level visual representations (pixels, V1-like). Taken together, these results suggest that rhesus monkeys and humans share a neural "shape" representation that directly underlies object perception.

23.584 **The clash of visual categories** Marlène Poncet[1,2](marlene.poncet@gmail.com), Ramakrishna Chakravarthi[3], Michèle Fabre-Thorpe[1,2]; [1]Université de Toulouse UPS Centre de Recherche Cerveau et Cognition France, [2]CNRS CerCo Toulouse, France, [3]School of Psychology, University of Aberdeen, UK

Categorization is very efficient. However it is unclear how multiple simultaneously active visual categories interact. Such interactions were tested in categorization tasks in which participants ignored a flashed prime, but responded to a 100ms target presented after an SOA of either 80 or

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180ms. The prime's category was either the same as the target category (congruent condition) or different (incongruent condition). In both experiments 1 (bird/non-bird categorization) and 2 (animal/non-animal categorization), responses to congruent trials were faster and more accurate than those to incongruent trials. More importantly, we tested two different types of incongruent primes: related and unrelated to the target. In Exp1, related incongruent primes belonged to the same superordinate category (e.g. dog), but unrelated ones did not (e.g. car). Related incongruent primes caused more interference than unrelated ones at both SOAs. In Exp2, each image belonged to one of three subclasses (air, water, ground). Whereas related primes belonged to the same subclass as the target, unrelated ones did not. As in Exp1, related incongruent primes caused more interference than unrelated ones, but only at long SOA. To explain these results, we propose a model based on the idea that categories are represented as hierarchical patterns of neuronal activity in infero-temporal cortex. When two objects share attributes (e.g. 'animal-ness'), their patterns overlap. Since related incongruent primes share more attributes with the target than unrelated ones, their patterns overlap more, increasing the difficulty to determine the target's category. Furthermore, target and incongruent related primes had far more overlap in Exp1 (e.g. bird primed by dog) than in Exp2 (e.g. bird primed by plane). Accordingly, interference was observed earlier in Exp1 than in Exp2. We conclude that residual activity in infero-temporal cortex affects subsequent categorization depending on the extent of overlap between activity patterns.

23.585 Contextual modulation of competing interpretations in early object recognition

Mohammed Islam[1](mislam19@fau.edu), Thomas Sanocki[2]; [1]Florida Atlantic University, [2]University of South Florida

One class of object recognition models posit that the brain extracts the global information of an object (e.g., shape) to generate multiple hypotheses, or "candidates," about the identity of an object. Additionally, context constrains and refines the initial candidates. If this is the case, is it then possible to modulate the interpretation of an object with contexts related to the different candidates? In a series of experiments, we presented participants with low pass filtered images of isolated objects in the periphery for 70 ms (followed by a mask). Participants were asked to identify the object in an open-ended response. We found that without context, many objects were often misinterpreted as another object sharing similar global shapes. These different interpretations were normed and categorized by their frequency of response. We then repeated the experiment with a new set of participants. This time, the images were preceded by either a fixation point or a scene. The object was congruent to the scene when the correct interpretation (e.g., football) matched the scene (e.g., football field), "falsely congruent" when the scene (cosmetic shop) matched the most frequent misinterpretation (lips), or incongruous when neither interpretation were related to the scene (farm). Interestingly, the data suggests that once a stimuli was interpreted as a certain object, the interpretation could not be refuted with an inappropriate context. However, the interpretation could be reaffirmed with an interpretation-congruent context as evident by a 20% increase in accuracy for the truly congruent condition and a 16% increase in false congruent condition (compared to presentation with no scenes). The data follows a pattern similar to that of a confirmation bias. Additionally, the current data suggests a more minimal role of context in the early stages of object recognition in which context does not inhibit competition.

23.586 Greater Oxygenation of Prefrontal Cortex During Information-Integration (vs. Rule-Based) Category Learning

Audrey Hill[1](audrey@knights.ucf.edu), Corey Bohil[1], Andrew Wismer[1]; [1]University of Central Florida

The COVIS theory of categorization (Ashby et al 1998, Psychological Review) posits that verbalizable (explicit) rule learning is mediated in part by prefrontal cortex (PFC), while nonverbalizable (implicit) rule learning is mediated chiefly by basal ganglia structures. COVIS also predicts that both learning systems attempt to determine each category response on each trial (i.e., the systems compete). On this basis, we predicted unique patterns of PFC blood flow depending on how participants performed on perceptual category learning tasks that required either selective attention to a single stimulus dimension ("rule-based" learning) or attention to multiple stimulus dimensions at once ("information-integration" learning). Participants completed rule-based and information-integration category learning tasks with two-dimensional stimuli (gabor patches varying in orientation and spatial frequency across trials). Hemodynamic response was measured in dorsolateral PFC using functional Near Infrared Spectroscopy (fNIRS). As expected, we found similar levels of oxygenated hemoglobin (Hbo2) in DLPFC early in learning for both conditions, and a divergence of activity level across tasks over the series of training blocks. This divergence was mediated by the type of rule used in each task. Participants using the incorrect rule type (a 1-dimensional rule) during information integration learning showed higher PFC activity than those using the appropriate rule type. These results support COVIS and suggest that these perceptual category learning tasks provide a dissociation that may be useful for examining changes in PFC integrity due to injury or aging.

23.587 P300 variability during target detection in natural images: Implications for single-trial classification

Jon Touryan[1](touryan@gmail.com), Amar Marathe[1], Anthony Ries[1]; [1]Human Research and Engineering Directorate, U.S. Army Research Laboratory

The P300 is one of the most prominent and well-studied event-related potentials (ERPs) in the literature. The P300 is also a primary discriminant signal for many brain-computer interface (BCI) systems. It has been well established that the P300 amplitude and latency, along with reaction time, are directly linked to target discriminability. However, since the majority of P300 studies using an odd-ball or target-detection paradigm have a fixed or unquantified level of target discriminability, it remains unclear how the P300 is systematically modulated by the discriminability of stimulus properties affecting target detection. In this study we quantified visual properties of target objects within a large ensemble of natural images (color photographs of an office environment). Using a rapid serial visual presentation (RSVP) paradigm, we were able to systematically measure the effect of these properties on both the behavioral reaction time and P300. We evaluated how stimulus properties affected the P300 amplitude and latency while controlling for reaction time variability by using response-locked ERPs. As expected, we found that several stimulus properties, such as target size and eccentricity, had a dramatic effect on the P300 amplitude. In contrast, no effect was observed on the response-locked P300 latency. Importantly, the performance of single-trial classifiers (linear discriminant functions) was affected to a similar degree by these stimulus properties. Our results articulate the challenge for developing classification approaches that are robust to stimulus induced variability in the P300 response.

23.588 Does Implicit Learning Play a Role in Base-rate Sensitivity?

Andrew Wismer[1](andrew.wismer@knights.ucf.edu), Corey Bohil[1]; [1]University of Central Florida

We explored the possibility that implicit learning plays a role in base-rate sensitivity during perceptual category learning. Participants learned to categorize simple stimuli (bar graphs varying in height from trail to trial) with unequal category base-rates (relative exemplar frequencies). Implicit learning was explored via manipulations previously used to test the COVIS (Competition between Verbal and Implicit Systems) theory of categorization. These included learning with different response types (making a categorization response on each trial vs. observational learning) and feedback delays (immediate corrective feedback after each response or after a 5 second delay on each trial). We also manipulated the salience of base-rate information by manipulating base-rate ratio (2:1 or 3:1), discriminability level (d'=1 or d'=2), and category structure training (pretraining or not on category structures prior to base-rate manipulation). We found that performance in response conditions was closer to optimal than performance in observational-learning conditions, and that performance was closer to optimal when feedback immediately followed a response. In other words, under manipulations known to disrupt implicit learning (observational learning, delayed feedback), performance clearly suffered. There was a strong interaction between these trends and category discriminability. When d' was lower and when category structure was not pre-trained (i.e., when the available perceptual information was less informative), the influence of base-rate information on decision-criterion placement was clearly stronger. These results suggest that implicit (or procedural) learning does indeed play a role in the learning of base-rate information.

Saturday Afternoon Talks

Saturday PM

Eye movements: Perception and mechanisms

Saturday, May 17, 2:30 - 4:15 pm
Talk Session, Talk Room 1
Moderator: Michele Rucci

24.11, *2:30 pm* **Natural vision effects on contrast sensitivity and their correlation with macaque V1 activity** James Niemeyer[1](James_Niemeyer@brown.edu), Michael Paradiso[1]; [1]Department of Neuroscience, Brown University

In a series of physiological and psychophysical experiments, our lab has previously shown that there are significant differences in brain representations and visual perception between natural vision and vision in laboratory experiments. Complex natural scenes and saccadic eye movements alter vision relative to experiments with simple stimuli flashed during prolonged fixation. Here we show that natural vision has significant effects on contrast sensitivity and that these effects are predictable from patterns of activation in macaque V1. Animals were trained to perform a 2AFC contrast discrimination task while recordings from V1 were made with 96 electrode Utah arrays. Conditions in which saccades brought stimuli into receptive fields were compared with other conditions that required fixation before stimuli were flashed. In both conditions the Gabor target stimuli were positioned on a complex natural scene background. We find, with similar visual input, that saccades across a complex scene alter contrast sensitivity relative to sensitivity with flashed stimuli. Specifically, contrast sensitivity is worse at lower spatial frequencies (1-4 cy/deg) but similar at higher spatial frequencies when a saccade brings the Gabor target into view. This effect is comparable to the reduced contrast sensitivity our lab has reported in similar human psychophysics experiments. The differences between "saccade" and "flash" contrast sensitivity functions is consistent with the effects of saccades across complex scenes on V1 spiking and LFP activity and the spatial frequency dependence of neural changes.Importantly, the spatial frequency dependence of the effects appears related to the statistics of natural scenes rather than magno/parvo processing differences. These findings are important for the characterization of V1 responses and perception in natural vision and for the clinical assessment of contrast sensitivity.

Acknowledgement: NSF BCS1261433 and NIH T32 EY018080

24.12, *2:45 pm* **Representing space in time during ocular drift** Claudia Cherici[1](cherici@bu.edu), Murat Aytekin[1], Michele Rucci[1,2]; [1]Department of Psychology, Boston University, Boston, MA 02215, USA, [2]Graduate Program in Neuroscience, Boston University, Boston, MA 02215, USA

How is space represented in the visual system?In an immobile eye, a stationary stimulus is necessarily encoded by the pattern of active receptors in the retina. But the eyes are always in motion, even during fixation, and eye movements make spatial information available in the temporal domain. Our recent work has provided strong evidence that the visual system also uses the temporal modulations resulting from fixational eye movements to encode fine spatial detail (Rucci et al., 2007; Kuang et al., 2012).Here we investigated the mechanisms of this encoding process.Subjects viewed a standard Vernier stimulus in complete darkness through a narrow vertical aperture, which allowed exposure of only one line at a time. They reported whether the top line was to the left/right of the bottom one. The aperture was stabilized on the retina, so that no spatial cues existed on the retina and the exposure of the two lines was solely determined by ocular drift (trials with saccades/microsaccades were discarded). To successfully perform this task, knowledge of eye movement was necessary, as the temporal pattern on the retina was, by itself, ambiguous. We conducted three separate experiments. In the first experiment, stimuli were presented on a fast CRT monitor.In the second experiment, to rule out possible contributions from the CRT phosphor persistence, stimuli were delivered by an array of ultra-fast LEDs.In the third experiment, we used a different technique for retinal stabilization in which stimuli were viewed through deflecting mirrors.Results were similar in all experiments: performance was significantly above chance with offsets of a few arcminutes.These results reveal that spatial information exclusively contained in the temporal structure of fixational modulations suffices to discriminate fine patterns, even in the absence of spatial displacements.

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24.13, *3:00 pm* **Binocular head/eye coordination during natural fixation** Martina Poletti[1](martinap@bu.edu), Murat Aytekin[1], Michele Rucci[1,2]; [1]Department of Psychology, Boston University, Boston, MA 02215, USA, [2]Graduate Program in Neuroscience, Boston University, Boston, MA 02215, USA

Incessant eye movements (ocular drift and tremor) shift the image on the retina during the brief fixation intervals in between saccades, the very periods in which visual information is acquired and processed.Because of the difficulty in accurately measuring microscopic eye movements, ocular drift has been typically studied with the head restrained, an artificial condition that minimizes recording artifacts.In this condition, ocular drift resembles Brownian motion, with loosely correlated or uncorrelated motion in the two eyes. Here, we examine ocular drift during natural head-free fixation, when the eyes also continually translate in space because of microscopic head movements.Traces of head and eye movements were acquired by means of the Maryland Revolving Field Monitor, an experimental device which enables oculomotor recordings at resolution higher than 1 arcmin during normal head-free viewing.We show that, contrary to the widespread assumption, ocular drift is under oculomotor control and highly correlated in the two eyes.The two eyes drifted faster during intersaccadic head-free fixation than under traditional head-restrained conditions and moved together to finely compensate for head movements, even when eye and head speeds were well below 2 deg/s.As a consequence, the resulting motion on the retina was comparable to that measured with the head restrained, when ocular drift was the only contributor to retinal image motion.We show that in the absence of this precise head/eye compensation during fixation: (1) the spatiotemporal frequency content of retinal stimulation would be severely altered; and (2) the retinal projection of the stimulus would quickly leave the foveola.Thus, our results show that the smooth inter-saccadic movement of the eye is under oculomotor control.During natural fixation, ocular drift is part of a compensatory mechanism, which aims at maintaining retinal image motion within an optimal range for vision.

Acknowledgement: National Institutes of Health grant EY18363 and National Science Foundation grant BCS-1127216

24.14, *3:15 pm* **High-precision control of binocular gaze** Matteo Valsecchi[1](matteo.valsecchi@gmail.com), Karl R. Gegenfurtner[1]; [1]Allgemeine Psychologie Abteilung, Justus-Liebig Universität Giessen

Humans can orient gaze extremely precisely on the fronto-parallel plane when high visual acuity is required. Yet, it is not known whether this extends to high-acuity natural tasks requiring an adjustment of vergence. We investigated the precision of binocular gaze control while observers performed a high-precision manual movement. The task involved hitting a target hole (1 mm diameter) in a plate with a hand-held needle (0.5 mm diameter) at 200 mm viewing distance. Binocular eye movements and the 3D-position of the needle tip were tracked. The six observers consistently set their point of gaze at the target height first, while the horizontal and depth adjustments took place more slowly as the needle approached the target. Microsaccade rate and amplitude decreased as the distance between needle and plate dropped below 3 mm. Microsaccades contributed to displace gaze between the needle and the target, since the horizontal point of gaze was located on average in between these two positions. This was not the case for depth, where the average point of gaze was centered on the needle tip. Moreover, changes in version and vergence were not coordinated during microsaccades. In a control experiment five observers moved gaze between marks on a slanted plane. Even when the inter-mark distance was 1 mm, instructing a saccade as small as the microsaccades in the needle experiment, we observed a coordinated displacement of the point of gaze on the horizontal and depth axis, although the vergence gain was relatively small (47.1%). Our results show that observers can control the position of binocular gaze very precisely in a high-acuity visual task, and that microsaccades contribute to displacing gaze between relevant objects. However, a coordinated control of version and vergence in small saccades is only observed if a movement of gaze along a slanted trajectory is explicitly instructed.

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24.15, *3:30 pm* **Eye-movements and the neural basis of context effects on temporal sensitivity** Qasim Zaidi[1](qz@sunyopt.edu), Robert Ennis[1], Dingcai Cao [2], Barry Lee[1,3]; [1]Graduate Center for Vision Research, SUNY College of Optometry, New York, NY, [2]Department of Ophthalmology and Visual Sciences, University of Illinois at Chicago, Chicago, IL, [3]Max Planck Institute for Biophysical Chemistry, Gottingen, Germany

It is well established that visual sensitivity is affected by context. The luminance of a surround region substantially affects the detection of luminance flicker at low frequencies, so that the Temporal Contrast Sensitivity Function is band-pass on dark or light surrounds, but low-pass on surrounds at the mean-level of the flicker. The cause of the effect remains controversial. Some explanations invoke enhancement of edge responses by lateral inhibition, others rely on transients caused by the miniature eye-movements involved in maintaining fixation. We replicated the psychophysical luminance results, and found that they also held for chromatic conditions: the TCSF for equiluminant red-green flicker was low-pass on mean-level surrounds, but was surprisingly band-pass on red or green surrounds. To identify the neural basis of the context effects, we used in vivo electrophysiological recordings of primate MC and PC ganglion cell responses to luminance and red-green modulations respectively. We measured cell responses at various distances from the modulation edge to test neuronal sensitivity to stationary edge contrast. To simulate the effects of eye movements, we measured cell responses to abruptly displaced target patches. Effects of stationary edge-contrasts on MC and PC cell responses were found to be minimal on all surrounds, excluding lateral inhibition as a mechanism for enhancement of responses to stationary edges. Abruptly displaced edges, however, evoked transient bursts or suppression of spikes. On mean-level surrounds, transient neural responses depended on the modulation phase, but responses were equal across all modulation phases on the polarized surrounds. Eye-movements thus enhanced detection of low-frequency flicker on mean-level surrounds, and a neurometric analysis supported a primary role for eye movements in the context effects on temporal sensitivity. These results also reveal that the transformation of spatial edges to transient retinal responses provides the neuronal substrate for detecting chromatic and luminance edges in natural scenes.

Acknowledgement: NEI EY007556, EY013312, EY019651

24.16, *3:45 pm* **Dissociating temporal inhibition of return and saccadic momentum across multiple eye-movement tasks** Steven G. Luke[1](steven_luke@byu.edu), Tim J. Smith[2], Joseph Schmidt[3], John M. Henderson[3]; [1]Department of Psychology, Brigham Young University, Provo, UT, USA, [2]Department of Psychological Sciences, Birkbeck, University of London, London, UK, [3]Institute for Mind and Brain and Department of Psychology, University of South Carolina, Columbia, SC, USA

Saccade latencies are longer before eye movements to recently fixated locations, a phenomenon known as oculomotor inhibition of return (O-IOR). However, latencies are also influenced by saccadic momentum: latencies are shortest before forward saccades and increase as the angular deviation (difference in direction) of the current and previous saccades increases. Using a within-subjects and within-items design, the present study attempted to dissociate the temporal and spatial consequences of O-IOR and saccadic momentum across three tasks: scene search, scene memorization, and aesthetic preference. Spatial analyses revealed facilitation of return (rather than inhibition) in all tasks: return saccades were more frequent in the data compared to a shuffled baseline. Initial temporal analyses suggested that O-IOR was weaker in search (16 ms) than in memorization or preference (28 & 25 ms, respectively). Saccadic momentum appears even if previous and current saccades are not closely matched in amplitude, while O-IOR appears only when saccades are matched in amplitude so the current saccade lands within the zone of IOR (within 4° of the previous fixation location), making it possible to dissociate the two phenomena. Fixation durations increased linearly as a function of angular deviation outside the IOR zone, but curvilinearly within the zone of IOR, revealing an additional penalty for return saccades beyond that accounted for by saccadic momentum. Furthermore, saccadic momentum and O-IOR differentially affected the frequency distribution of fixation durations. Saccadic momentum shifted the mean of the distribution's Gaussian component, lengthening most fixations, while O-IOR only influenced the skewness of the distribution (the exponential component), lengthening a subset of fixations. Interestingly, when dissociated in this way, O-IOR was equivalent in magnitude across tasks while saccadic momentum was not present in search. These results suggest that O-IOR and saccadic momentum are independent phenomena, and that O-IOR is task-independent while saccadic momentum is not.

Acknowledgement: This work was supported by grant BCS-1151358 from the National Science Foundation to JMH.

24.17, *4:00 pm* **The pupillary light response reflects eye-movement preparation** Sebastiaan Mathôt[1](s.mathot@cogsci.nl), Lotje van der Linden[1], Grainger Jonathan[1], Françoise Vitu[1]; [1]Laboratoire de Psychologie, CNRS, Aix-Marseille Université

When the eyes are exposed to an increased influx of light, the pupils constrict. The pupillary light response (PLR) is traditionally believed to be purely reflexive and not susceptible to cognitive influences. In contrast to this traditional view, we report here that the PLR is initiated during the preparation of an eye movement towards a bright (or dark) stimulus, even before the eyes set in motion. Participants fixated a central gray area and made a saccadic eye movement towards a peripheral target. Using gaze-contingent display changes, we manipulated whether or not the brightness of the target was the same during and after eye-movement preparation. More specifically, on some trials we changed the brightness of the target as soon as the eyes set in motion, thus dissociating the preparatory PLR (i.e. to the target brightness during saccade preparation) from the 'regular' PLR (i.e. to the target brightness after the saccade). We show that a preparatory PLR is initiated during saccade preparation, approximately 100 ms before saccade onset. This preparatory response allows the pupil to track luminance changes in visual input more rapidly than would be possible without preparation. Strikingly, a purely preparatory luminance-related pupillary response was triggered even when a saccade was prepared towards a bright (or dark) stimulus that was removed before being brought into central vision. We link our findings to the pre-saccadic shift of attention: The pupil adjusts its size to the brightness of a to-be-fixated stimulus, as soon as attention shifts towards the target of an upcoming saccade. Our findings illustrate that the PLR is a dynamic movement that is tightly linked to visual attention and eye-movement preparation.

Acknowledgement: ERC Grant nr. 230313 to Jonathan Grainger

Face Perception

Saturday, May 17, 2:30 - 4:15 pm
Talk Session, Talk Room 2
Moderator: Christian Wallraven

24.21, *2:30 pm* **An Account of the Face Configural Effect** Irving Biederman[1,2](bieder@usc.edu), Xiaokun Xu[2], Manan Shah[2]; [1]Neuroscience, University of Southern California, [2]Psychology, University of Southern California

A striking phenomenon in face perception is the configural effect in which a difference in a single part appears more distinct in the context of a face than it does by itself (Tanaka & Farah, 1992, Fig. 1). Because the face context is identical it would be expected to increase search complexity, rendering recognition/discrimination more—not less—difficult. Remarkably, there has never been a biologically plausible explanation of this fundamental signature of face recognition. We show that the configural effect can be simply derived from a model composed of overlapping receptive fields (rfs) characteristic of early cortical simple-cell tuning but also present, possibly without the linking of spatial frequency (SF) to rf size, in face-selective areas. Because of the overlap in rfs, the difference in a single part (between target and foil) is not only represented in the rfs centered on it, but also propagated to larger rfs centered on distant parts of the face. Similarity values computed from the model between pairs of faces and pairs of face parts closely matched the recognition accuracy of human observers who had learned a set of faces composed of composite parts and were tested on wholes (Which is Larry?) and parts (Which is Larry's nose?). That it is the larger rfs rather than low SFs that account for the configural effect was documented in an experiment in which the stimuli were high vs. low passed (Fig. 2). The configural effect was found to be largely insensitive to SF. The retention of a configural (rather than a part) representation may be unique to the representation of faces and explains why distinguishing similar faces (unlike distinguishing objects of equivalent physical similarity) is ineffable (because we do not have cognitive access to the rf activation values) and so adversely affected by inversion and contrast reversal.

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24.22, *2:45 pm* **Perceptual integration of kinematic components for the recognition of emotional facial expressions** Enrico Chiovetto[1](enrico.chiovetto@klinikum.uni-tuebingen.de), Cristóbal Curio[2], Dominik Endres[1], Martin Giese[1]; [1]Section for Computational Sensomotorics, Department of Cognitive Neurology, Hertie Institute for Clinical Brain Research, Centre for Integrative Neuroscience, University Clinic Tübingen, Tübingen, Germany., [2]Max Planck Institute for Biological Cybernetics, Dept. Human Perception, Cognition and Action, Tübingen, Germany

There is evidence in both motor control (Flash and Hochner 2005; Chiovetto and Giese, 2013) as well as in the study of the perception of facial expressions (Ekman & Friesen, 1978) showing that complex movements can be decomposed into simpler basic components (usually referred to as 'movement primitives' or 'action units'). However, such components have rarely been investigated in the context of dynamic facial movements (as opposed to static pictures of faces). METHODS. By application of dimensionality reduction methods (NMF and anechoic demixing) we identified spatio-temporal components that capture the major part of the variance of dynamic facial expressions, where the motion was parameterized exploiting a 3D facial animation system (Curio et al, 2006). We generated stimuli with varying information content of the identified components and investigated how many components are minimally required to attain natural appearance (Turing test). In addition, we investigated how perception integrates these components, using expression classification and expressiveness rating tasks. The best trade-off between model complexity and approximation quality of the model was determined by Bayesian inference, and compared to the human data. In addition, we developed a Bayesian cue fusion model that correctly accounts for the data. RESULTS. For anechoic mixing models only two components were sufficient to reconstruct three facial expressions with high accuracy, which is perceptually indistinguishable from original expressions. A simple Bayesian cue fusion model provides a good fit of the data on the integration of information conveyed by the different movement components. References: Chiovetto E, Giese MA. PLoS One 2013 19;8(11):e79555. doi: 10.1371/journal.pone.0079555. Curio C, Breidt M, Kleiner M, Vuong QC, Giese MA and Bülthoff HH. Applied Perception in Graphics and Visualization 2006: 77-84. Ekman P and Friesen W. Consulting Psychologists Press, Palo Alto, 1978. Flash T, Hochner B. Curr Opin Neurobiol 2005; 15(6):660-6.

Acknowledgement: 8311 AMASupported by: EU Commission, EC FP7-ICT-24RSi, Deutsche Forschungsgemeinschaft: DFG GI 305/4-1, DFG GZ: KA 1258/15-1, German Federal Ministry of Education and Research: BMBF, FKZ: 01GQ1002A, European Commission, Fp 7-PEOPLE-2011-ITN(Marie Curie): ABC PITN-GA-011-290011, HBP FP7-ICT-2013-FET-F/ 604102 Koroibot FP7-ICT-2013-10/ 611909.

24.23, *3:00 pm* **Configural and featural facial information: integrality in normal face processing, separability in prosopagnosia** Ruth Kimchi[1,4](rkimchi@research.haifa.ac.il), Marlene Behrmann[2], Galia Avidan[3], Rama Amishav[4]; [1]Department of Psychology, University of Haifa, [2]Department of Psychology, Carnegie Mellon University, [3]Department of Psychology, Ben Gurion University of the Negev, [4]Institute of Information Processing and Decision Making, University of Haifa

Adults' expertise in face recognition has been attributed to their ability to engage in holistic processing. Exactly what constitutes holistic processing has remained controversial, however. In an attempt to understand the nature of face representation and processing, we examined how configural and featural information interact during face processing in a group of individuals with congenital prosopagnosia (CP) and matched controls, using Amishav and Kimchi's (2010) version of Garner's speeded classification task. This task examines the ability to process one dimension of a multidimensional visual stimulus, while ignoring another dimension, using selective attention measures, and provides a powerful test of perceptual separability between stimulus dimensions. When classifying upright faces varying in features (eyes, nose, and mouth) and configural information (inter-eyes and nose-mouth spacing), normal observers evince symmetric Garner interference: they were unable to selectively attend to features without experiencing interference from irrelevant variation in configuration, and vice versa, indicating that featural information and configural information are integral in normal face processing. In contrast, the CPs showed no Garner interference: they could attend to configural information without interference from irrelevant featural information, and vice versa, indicating that featural information and configural information are perceptually separable in CP's face processing. These results indicate that CPs do not perceive faces holistically; rather, they process featural and configural information independently. This finding not only elucidates the underlying perturbation in CP but also confirms that intact face processing is characterized by the perceptual integrality of configural and featural information.

24.24, *3:15 pm* **Retinotopic priors for eyes and mouth in face perception and face sensitive cortex** Benjamin de Haas[1,2,3](benjamindehaas@gmail.com), D. Samuel Schwarzkopf[3], Ivan Alvarez[4], Linda Henriksson[5,6], Nikolaus Kriegeskorte[5], Geraint Rees[1,2]; [1]Institute of Cognitive Neuroscience, University College London, [2]Wellcome Trust Centre for Neuroimaging, University College London, [3]Division of Psychology and Language Sciences, University College London, [4]Institute of Child Health, University College London, [5]MRC Cognition and Brain Sciences Unit, Cambridge, [6]Brain Research Unit, O.V. Lounasmaa Laboratory, Aalto University, Finland

Gaze patterns towards faces typically concentrate in a region that includes eyes and mouth as upper and lower boundaries (e.g. van Belle et al., 2010). This implies a natural retinotopic bias– eyes will appear more often in the upper than lower visual field and vice versa for mouths. We asked whether this bias is reflected in perceptual sensitivity and cortical processing of face features. In a behavioral experiment we tested whether recognition performance for eyes and mouths varied with retinotopic location. In each trial healthy human participants (n=18) saw a brief (200 ms) image of a single eye or mouth, accompanied by a noise mask. Recognition performance was tested in a match-to-sample task. In a canonical condition eye and mouth stimuli were presented in typical upper and lower visual field locations while in a second condition these locations were reversed. We found strong evidence for the predicted feature by location interaction ($F=21.87$, $P<0.001$). Recognition of eyes was significantly better for upper vs. lower visual field locations ($t=3.34$, $P<0.01$) while the reverse was true for mouth recognition ($t=3.40$, $P<0.01$). We speculated this might reflect a correlation between spatial and feature preferences of neural populations in face sensitive cortex. Based on this hypothesis we performed an, fMRI experiment (n=21) using identical stimuli. Preliminary results indicate that patterns evoked by eyes vs. mouths were separable significantly better than chance in inferior occipital gyrus (IOG) and fusiform face area (FFA) of either hemisphere. Crucially, separability of patterns was significantly better for the canonical condition in right IOG ($t=2.20$, $P<0.05$) and a similar trend was observed for right FFA ($t=1.92$, $P=0.07$). These results indicate that sensitivity to face features is spatially heterogeneous across the visual field and in human face-sensitive cortex. Face feature sensitivity thus likely reflects input statistics.

Acknowledgement: This work was supported by the Wellcome Trust (BdH, DSS, GR), the European Research Council (DSS, BdH) and the Medical Research Council (NK)

24.25, *3:30 pm* **Data driven identification of functional organization** Jason Webster[1](jwebst@uw.edu), Ione Fine[1]; [1]Psychology, University of Washington, Seattle, WA

Purpose: Current fMRI methods for examining cortical functional organization require assumptions about either stimulus category boundaries or the region of interest (ROI). Conventional fMRI localizers rely on statistical contrasts between predefined conditions, requiring assumptions about how stimuli should be categorized. Representational similarity analysis, which quantifies the similarity of responses within a region of interest to a set of stimuli, requires a predefined ROI that does not contain cortical areas with diverse selectivity profiles. Here, we describe a method that identifies cortical regions with similar selectivity profiles across a stimulus set without assumptions about either stimulus categorical structure or the ROI. We evaluated our approach by using it to identify known category selective areas in ventral temporal cortex. Methods: Two subjects passively viewed short video clips of faces, bodies, scenes, objects, scrambled objects, and uniformly colored screens. There were 12 stimuli in each category and ten repetitions per stimulus. For each vertex on the cortical surface, we calculated a vector of 72 beta-weights that represented the response to each stimulus. A dissimilarity matrix was constructed for these beta-weights, which was then sorted to cluster vertices with similar beta-weight vectors. Results: When projected onto the cortical surface, vertex clusters formed spatially contiguous regions. Both the spatial extent of these regions and the profile of responses within these ROIs were highly replicable using an independent dataset. A subset of these regions almost perfectly overlapped with conventionally identified category selective regions (e.g. PPA, FFA), while others were novel. Future work with a more diverse stimulus dataset will investigate the selectivity of these novel clusters. Conclusions: Our method successfully identifies ROIs with similar responses across a stimulus set without requiring assumptions about stimulus categorical structure or the region of interest.

Acknowledgement: NIH Computational Neuroscience Training Grant

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24.26, *3:45 pm* **Making eye contact without awareness** Apoorva Rajiv Madipakkam[1,2](apoorva-rajiv.madipakkam@charite.de), Marcus Rothkirch[1], Erik Rehn[3], Philipp Sterzer[1,3]; [1]Visual Perception Laboratory, Department of Psychiatry, Charité – Universitätsmedizin Berlin, Berlin, Germany, [2]International Graduate Program Medical Neurosciences, Charité – Universitätsmedizin Berlin, Berlin, Germany , [3]Bernstein Center for Computational Neuroscience, Berlin, Germany

Gaze direction is an important social cue that gives us a wealth of information about others' intentions and focus of attention. Evidence suggests that faces with direct gaze capture attention and receive prioritized visual processing even outside conscious awareness (Stein, Senju, Peelen, & Sterzer, 2011; Chen & Yeh, 2012). However, the behavioural effects of this preferential processing of direct gaze outside of awareness are unknown. To address this question, we rendered faces with direct and averted gaze invisible using interocular suppression. Participants' awareness was assessed based on objective criteria with a 2-alternative forced choice (2-AFC) task. We recorded eye movements to investigate whether humans have a preference for establishing mutual eye contact with faces that are fully suppressed from awareness. This provided us with a direct measure of their behavioural responses during the unconscious processing of the stimuli. We found that saccades were preferentially guided towards faces with direct eye gaze compared to faces with averted gaze even though the faces were invisible. This oculomotor preference suggests that a rapid and automatic establishment of mutual eye contact constitutes a biological advantage, which could be mediated by fast subcortical pathways in the human brain.

24.27, *4:00 pm* **Valence and arousal underlie evaluation of emotional and conversational facial expressions across cultures** Christian Wallraven[1](christian.wallraven@gmail.com), Ahyoung Shin[1], Felix Biessmann[1]; [1]Brain and Cognitive Engineering, Korea University

Facial expressions are one of the most important ways of non-verbal communication for humans. To date, most research in this field has focused solely on emotional aspects, largely neglecting the communicative and conversational aspects of expressions. Furthermore, although there is evidence for some degree of cross-cultural universality among emotional expressions, much less is known about how facial expressions in general are perceived across cultures. Here, we investigate the structure of the complex space of both emotional and conversational expressions in a cross-cultural context. The two experiments reported here used matching video sequences of 27 expressions from both the KU (Korean) facial expression database and the MPI (German) facial expression database (each expression was shown by 6 actors, totaling 162 videos from each database). In the first experiment, four groups (each n=20) of native German and Korean participants were asked to group the sequences of the German or Korean databases into clusters based on similarity. This grouping data yielded four different confusion matrices. In the second experiment, another four groups of participants (each n=20) from both cultures were asked to rate each video according to 13 emotional and conversational attributes. This rating data yielded an averaged 13-dimensional vector for each sequence. For each of the four grouping/rating data-pairs, we then used kernel canonical correlation analysis (KCCA) to determine a two-dimensional embedding of expressions that best explained both grouping and rating data. Although other attributes contributed as well, the two dimensions recovered by KCCA showed maximal correlation with valence and arousal ratings – this was true regardless of participants' cultural backgrounds or of the database that was used. Our results show that evaluative dimensions for both German and Korean cultural contexts are highly similar, confirming that cultural universals exist even in this complex space of emotional and conversational facial expressions.

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Spatial vision: Crowding and context

Saturday, May 17, 5:15 - 6:45 pm
Talk Session, Talk Room 1
Moderator: Ruth Rosenholz

25.11, *5:15 pm* **Crowding, grouping, timing** Mauro Manassi[1](mauro.manassi@epfl.ch), Aaron Clarke[1], Vitaly Chicherov[1], Michael H. Herzog[1]; [1]Laboratory of Psychophysics, Brain Mind Institute, École Polytechnique Fédérale de Lausanne

In crowding, target perception is deteriorated by flanking elements. For example, when a vernier is flanked by two lines of the same length, vernier offset discrimination strongly deteriorates. Interestingly, changing the color of the flankers can reduce crowding (uncrowding). Similarly, when the flanking lines are part of a cube, i.e., a good Gestalt, crowding is weak. Conversely, however, scrambling the lines of the cubes, i.e., a "bad" Gestalt, leads to strong crowding. We proposed that crowding is strong when target and flankers group (two-lines, scrambled cubes). Crowding is weak when the target ungroups from the flankers (two flanking lines with different color, cubes). Here, we show, first, that when target and flankers group (strong crowding), crowding is unaffected by stimulus duration. Two same-length flankers presented for 20 ms lead to similar performance as when presented for 150 ms. Second, in uncrowding with flankers of different color (and other basic feature differences), performance is again unaffected by stimulus duration. Third, in uncrowding with cubes, duration matters. For short durations (20 ms), crowding is strong and only for longer stimulus durations (from 120 ms on) does crowding decrease. We suggest that, for short durations, the brain cannot process the good Gestalt of the cubes. The representation of the cube's lines is "unstructured", as in the scrambled cubes, and hence crowding is strong. Interestingly, a short preview (20 ms duration) of only the cubes strongly reduces crowding, even when the preview is presented one second before the "crowded" stimulus. Our results suggest that uncrowding emerges in a slow, recurrent manner, with iconic memory playing an important role.

Acknowledgement: Swiss National Science Foundation (SNF)

25.12, *5:30 pm* **Effects of grouping on crowding with informative flankers** Shaiyan Keshvari[1](shaiyan@mit.edu), Ruth Rosenholtz[1,2]; [1]Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, [2]Computer Science and Artificial Intelligence Laboratory, Massachusetts Institute of Technology

Previous work in visual crowding has demonstrated that grouping (e.g. Gestalt laws of grouping) between target and flankers leads to decreased performance (more crowding) than when flankers do not group with the target (Manassi et al, 2012; Chakravarthi & Pelli, 2011). In these experiments, however, the strength of grouping was limited by the requirement that the flanker identities be uninformative for the task, such that knowing the identity of a flanker does not help identify the target. For example, the letter array ANC has less grouping than the array NNN, and knowing the flanker identities in the first case does not explicitly help identify the target. Our recent model of crowding (Balas et al, 2009), which postulates that crowding is a consequence of a high-dimensional pooling representation in the visual periphery, interestingly predicts a reduction in crowding for some situations in which the flankers are informative. Here we test whether grouping between informative flankers and the target is advantageous. To control for informativeness of the flankers (and avoid observers doing the task with the less-crowded flankers) we cross flanker informativeness (ANC vs. NNN) with target-flanker grouping by feature similarity, for several established classes of stimuli (letters, Gabor patches, etc.) and features (orientation, color, etc.). We find that for informative flankers (NNN condition), performance is better when the target shares the same feature as the flankers than when the target and flankers are different along that feature. By treating crowding as an artifact of a compressed peripheral representation, the role of grouping in crowding can be examined in more detail. This research has implications for understanding crowding in natural scene perception, where flankers are more likely to be informative about the target.

Acknowledgement: This work was funded in part by NIH-NEI grant (EY021473) to R. Rosenholtz.

25.13, *5:45 pm* **Saccades alter crowding in the parafovea** Laura Walker[1,2](laura@ski.org), Saeideh Ghahghaei[1]; [1]The Smith-Kettlewell Eye Research Institute, [2]Envision, Inc

Crowding is typically studied during fixation with covert attention to the target, and demonstrates a radial-tangential anisotropy (Toet & Levi, 1992). During natural vision, eye movements necessarily alter the relative

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relationship of flankers to targets. Here we examine how saccades impact crowding of parafoveal targets. Four participants reported the orientation of a brief gabor target (100ms) in the upper or lower parafovea while keeping their gaze at a central fixation. In separate blocks, target eccentricity and flanker condition were manipulated (absent, radial, tangential). The crowding factor (CF: ratio of crowded to uncrowded conditions) was determined by adaptively changing the size and target-flanker distance (Petrov & Meleshkevich, 2011). For all participants, CF was greater for radial versus tangential configurations and CF increased with eccentricity. In the second experiment, participants made three, timed saccades between four targets. During fixations on the second and third targets, stimuli analogous to experiment 1 were displayed for 100ms during each "look" in a gaze-contingent manner. Participants were again asked to report the orientation of the gabor. Discrimination was not impacted by eye movements in the unflanked condition. When flankers were present and radial/tangential configurations preserved for each "look", the hallmark anisotropy was preserved. When the eye movement served to rotate the flanker configuration with respect to the target, the two looks were cumulative and the CF fell between the radial and tangentially crowded bounds. Notably, the addition of saccades altered the CF as a function of eccentricity. Rather than a monotonically increasing function, the CF increased for targets near the fovea decreased for targets outside the parafovea. This change may be related to the spatial profile of attention during a sequence of eye movements.

Acknowledgement: NIH R01-EY018004

25.14, *6:00 pm* **Peripheral object recognition with informative natural context** Ruth Rosenholtz[1,2](rruth@mit.edu), Maarten Wijntjes[3]; [1]CSAIL, [2]Dept. of Brain & Cognitive Sciences, MIT, [3]Perceptual Intelligence Lab, Delft University of Technology, Netherlands

Research suggests that, due to capacity limitations, the visual system pools information over sizable regions, which grow linearly with eccentricity. In many artificial experiments, this causes pooling over uninformative "flankers", leading to crowding. However, under natural circumstances, objects are typically surrounded by informative context. In normal viewing, how does the harmful effect of pooling over a large, potentially complex region (i.e. crowding) trade off against the beneficial effect of additional context? We conducted a recognition experiment in which we varied the size of the contextual region surrounding the object. 656 objects were randomly selected from a fully annotated picture database (SUN 2012). Objects were presented at 10 degrees from the fovea, and subtended 4 degrees visual angle. In one condition, the objects appeared isolated from the background. Otherwise, the objects appeared within a circular cropping of the original picture, with radius varying from 1 (object size) to 5 times the object size. In addition, we examined accuracy identifying the object from the context alone (largest window size into the scene, object occluded by a patch the size of the smallest window). Recognition performance was 36% for the cut out objects, then increased monotonically from 45% to 71% with increasing window size, showing no detrimental effect of increasing the surround to include the typical "crowding zone". Performance with context alone was 29% correct. These results confirm that there are object recognition benefits to pooling information over a large region. The visual system, faced with capacity limitations, has made a reasonable compromise. On average, for real world identification, contextual information more than makes up for the loss of information underlying crowding.

Acknowledgement: NIH-NEI EY021473

25.15, *6:15 pm* **Highly abnormal visual context processing in older adults** Michael Melnick[1,2](mmelnick@u.rochester.edu), Kevin Dieter[3], Duje Tadin[1,2]; [1]Center for Visual Science & Dept. of Brain and Cognitive Sciences, University of Rochester, Rochester, NY, USA 14627, [2]Department of Ophthalmology, University of Rochester School of Medicine, Rochester, NY, USA 14627, [3]3Vanderbilt Vision Research Center, Department of Psychology, Vanderbilt University, Nashville TN, USA

Visual context can have strong effects on the appearance of local visual elements. Although these contextual illusions are examples of non-veridical visual perception, they are functionally advantageous because they enhance relative differences among visual features (Albright & Stoner, 2002). A neural implementation of such contextual effects must strike a balance between the enhancement of feature differences and the veridical representation of the same features. Thus, both atypically weak or strong contextual modulations are likely maladaptive as both constitute departures from typical vision. Given the growing evidence for visual processing changes in old age, including changes in inhibitory efficacy, we aimed to determine how contextual processing changes with age. We administered a large battery of contextual tasks to 50 older adults (mean age = 68) and 29 young adults. The results revealed drastically different contextual processing in older adults relative to younger observers. Repulsive surround tilt and repulsive surround motion illusions were on average twice as strong in older adults ($p < 0.0001$ and 0.01, respectively). Similarly, brightness induction by the surround was also about twice as strong in older subjects ($p < 0.001$). On the other hand, aging was linked with a 25% reduction in surround contrast effect ($p = 0.02$). We also found weaker spatial suppression with moving stimuli in older adults ($p < 0.0001$), replicating previous results (Betts et al., 2005). No group differences were found for the Ebbinghaus size illusion ($p = 0.43$). Interestingly, performance across these tasks was largely uncorrelated for both groups, arguing against a global contextual processing deficit and ruling out low-level explanations (e.g., age-related reduction in retinal luminance). Evidently, older adults exhibit a highly atypical pattern of visual context processing. Given the important role of contextual modulations in visual perception, these strong abnormalities are likely to have large effects on overall visual function.

Acknowledgement: y National Institutes of Health grant EY019295 (to D.T.) and Core grant P30 EY001319.

25.16, *6:30 pm* **Localized BOLD fMRI Responses in V1 Reflect a Task-Dependent Mixture of Luminance Contrast and Pattern Context during Iso-Orientation Surround Suppression** Michael-Paul Schallmo[1](schal110@umn.edu), Stefan R. Brancel[2], Andrea N. Grant[3], Cheryl A. Olman[2]; [1]Graduate Program in Neuroscience, University of Minnesota, [2]Department of Psychology, University of Minnesota, [3]Center for Magnetic Resonance Research, University of Minnesota

Functional MRI data are typically interpreted as measurements of average, local neural population activity. However, when the local neural population encodes multiple aspects of a stimulus or behavioral state, quantitative inference becomes more difficult. For example, interactions between neighboring visual stimuli may confound interpretation of the local BOLD signal. To better understand the contributions of task, timing, and stimulus geometry to the fMRI signal, we conducted four experiments measuring the fMRI response to small sinusoidal grating patches with either parallel or orthogonal surrounding gratings. Experiments were conducted in a 7 Tesla scanner with 1.2mm isotropic resolution. Targets were presented at 8%, 16% and 32% contrast while manipulating: (1) spatial extent of parallel (strongly suppressive) or orthogonal (weakly suppressive) surrounds, (2) stimulus onset asynchrony between the target and surround, (3) temporal structure of stimulus presentation (block vs. event-related design), and (4) locus of spatial attention. Previous work has shown that the localized fMRI response in primary visual cortex (V1) during iso-orientation suppression does not reliably increase with greater luminance contrast for small targets (Schumacher & Olman, 2010), and can be predicted by long-range patterns too large to be detected by V1 receptive fields (Joo, Boynton & Murray, 2012). Consistent with these findings, we observed that the localized V1 response to sinusoidal grating patches reliably indicated target contrast only when attention was directed away from the stimulus, or when a blocked stimulus presentation was used. For attended event-related stimuli, the V1 fMRI response to luminance contrast was conflated with higher-order pattern responses, reflecting second-order contrast between the target stimuli and flanking context. This work highlights the important role of both attention and pattern perception during early visual processing, as well as our limited ability to make inferences about diverse local neural activity from the fMRI signal.

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Visual search: Eye movements and mechanisms

Saturday, May 17, 5:15 - 6:45 pm
Talk Session, Talk Room 2
Moderator: Christian P. Jansen

25.21, *5:15 pm* **Reinforcement modifies visual search in a structured background** Celine Paeye[1,2](celine.paeye@gmail.com), Alexander Schütz[1], Karl Gegenfurtner[1]; [1]Department of Psychology, Justus Liebig University, Gie en, Germany, [2]Laboratoire Psychologie de la Perception, University of Paris Descartes, France

Reinforcement has been shown to play a role for eye movement control in visual search using simple stimuli. For instance, saccades made towards specific locations in a uniform background were followed with a rewarding tone (Chukoskie et al., 2013) or specific sequences of saccades between dif-

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ferent items led to target presentations (Paeye & Madelain, 2012). We tested whether visual consequences, displayed after saccades with specific landing positions or movement vectors, can change eye movement behavior in visual search performed in a homogeneously structured background. Participants were instructed to search for a Gabor patch in a 1/f background noise where no target was visible at the beginning of the trial. We used a gaze-contingent display to present the target at saccade offset more often after saccades that landed in a specific quadrant (experiment 1) or after saccades that were moving at a specific angle (experiment 2). Baseline trials did not contain any targets and were cancelled after the execution of ten saccades. Between baselines trials and trials at the end of reinforcement, the proportions of saccades towards the frequently reinforced quadrant or those moving at the frequently reinforced angle nearly tripled. Moreover, changing the reinforcement criteria in favor of other landing positions or movement vectors induced corresponding increases in the proportions of saccades. These results show that seeing the target after specific eye movements determines saccade sequences during visual search in a structured background. They extend the work of Najemnik and Geisler (2005) who elaborated a Bayesian model to account for human visual search. These authors proposed that an ideal searcher chooses fixation locations such that information gain is maximized. By directly manipulating saccadic consequences we showed that an operant learning process can also guide changes in visual search.

Acknowledgement: DFG grant SCHU 2628/2-1

25.22, *5:30 pm* **The dominance of color in guiding visual search: Evidence from mismatch effects** Robert Alexander[1](rgalexander.vision@gmail.com), Gregory Zelinsky[1,2]; [1]Department of Psychology, Stony Brook University, [2]Department of Computer Science, Stony Brook University

We quantified the features used in a visual search task in terms of mismatch costs—the decrement in search performance caused by a difference between target appearance at preview and target appearance in the search display. In nine experiments using real-world objects arranged into an eight-item search display, we tested the role of hue, shape, and orientation mismatch (25 levels per feature dimension) on search guidance and target verification. Results showed that shape and orientation guide search only when color is not available (i.e. grayscale target cues and search displays). Even in those grayscale cases, shape and orientation mismatch effects emerged only later during search (after fixation on a distractor). However, color mismatch effects appeared early (in the first fixated object) and were large in magnitude compared to orientation and shape, demonstrating that hue dominates search from the very first eye movements. Effects of mismatch on target verification followed a similar pattern, suggesting that similar comparison processes underlie guidance and verification. Additionally, mismatch effects were larger when participants were uncertain of what feature dimension would change and when the mismatching dimension was valid on a larger proportion of trials, demonstrating that participants weight features based on their expectancies (although this does not appear to happen on a trial-by-trial basis, contrary to the conclusions of studies using simple stimuli). We also found that when more than one feature dimension was mismatched on a given trial, the mismatch cost was superadditive, which contradicts most models of search assuming a linear summation across feature dimensions. Lastly, the fact that guidance was largely unaffected by orientation and shape mismatch suggests that surprisingly little information from these features is extracted from the target preview and used in search, perhaps reflecting the use of a categorical template and features retrieved from visual long-term memory.

Acknowledgement: NSF grants IIS-1111047 and IIS-1161876, NIMH Grant R01-MH063748

25.23, *5:45 pm* **Finding people in scenes: neural decoding target presence during search of dynamic scenes** Eamon Caddigan[1,2](eamon.caddigan@psych.ucsb.edu), Barry Giesbrecht[1,2], Miguel Eckstein[1,2]; [1]Institute for Collaborative Biotechnologies, University of California Santa Barbara, [2]Department of Psychological & Brain Sciences, University of California Santa Barbara

Searching for a potentially moving person in a dynamic crowd is a common visual task, but little is known about how we do this. Recent work has shown that the frontoparietal attention network, particularly the intraparietal sulcus (IPS), represents the presence of targets during the search for objects in static natural scenes (Guo et al., 2012). Here, we used fMRI and multivoxel pattern analysis to determine whether the IPS contains information about the presence of a target person in a dynamic scene depicting a crowd. In Experiment 1, separate groups of participants watched a series of brief (8.75 s) videos during fMRI and searched for either a particular person or for an object (a skateboard), each of which was present on 50% of the trials. For both people searchers and object searchers, decoding accuracy using BOLD activity extracted from IPS was significantly above chance (person searchers=63% SEM=0.020, $p < 0.01$; object searchers=71% SEM=0.014, $p < 0.01$). In Experiment 2, a single group of observers watched videos and alternated between searching for a person and searching for a skateboard. Across conditions, target presence was again decoded from activity in IPS significantly above chance (person trials=63%, SEM=0.026, $p < 0.01$; object trials=64%, SEM=0.013, $p < 0.01$). Moreover, IPS activity was able to predict the target of the search (person vs. skateboard) significantly above chance (64% correct classification, SEM=0.024, $p < 0.01$). Together, these results show that the IPS plays an important role in visual search by representing the presence of both person and object targets, as well as the identity of the search target.

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25.24, *6:00 pm* **The influence of salience-driven processes in overt visual selection** Mieke Donk[1](w.donk@vu.nl); [1]Department of Cognitive Psychology, Vrije Universiteit Amsterdam

Eye movements emitted immediately after the presentation of a visual display are strongly driven by the relative salience of individual items in the visual field. However, to date it is unclear how salience affects oculomotor selection beyond an initial eye movement. The present contribution aims to provide an answer to the question how salience-driven control unfolds over a sequence of eye movements. The results of several studies will be reported showing that eye movements elicited shortly after the presentation of a display were primarily salience driven. Subsequent eye movements were unaffected by salience but the effects of salience could be reinstated by a local salience increase, even when this increase was presented during an eye movement. The results are in line with the idea that the transsaccadic salience representation does not hold information about the relative salience of objects but only contains information concerning the locations of distinct objects in the visual field.

25.25, *6:15 pm* **The low-prevalence effect is due to failures of attention, not premature search termination or motor errors: Evidence from passive search and eye-movements.** Michael Hout[1](mhout@nmsu.edu), Steve Walenchok[2], Stephen Goldinger[2], Jeremy Wolfe[3]; [1]New Mexico State University, [2]Arizona State University, [3]Brigham and Women's Hospital, Harvard Medical School

Infrequently encountered targets are missed disproportionately often. This low prevalence effect (LPE) is a robust problem with significant societal consquences (Wolfe et al., 2007). Fleck & Mitroff (2007) suggested that the LPE might reflect premature search termination or response errors. Alternative models argue that prevalence influences observers' decision-making criteria and quitting thresholds. In four experiments with nearly 400 participants, we examined the LPE using standard visual search (with eye-tracking), and two variants of a passive RSVP task. In the RSVP task, sequences of stimuli with or without a target are presented to observers who respond present/absent after the sequence ends (following Hout & Goldinger, 2010). In all experiments, people looked for two target categories simultaneously. The low-prevalence target appeared much less often than its counterpart, while overall target prevalence was 50% in all conditions. In some conditions, people searched for the categories "teddy bear" and "butterfly" among other real-world objects. In other conditions, people searched for specific bears or butterflies among distractors from the same two categories. Results: 1) In standard search, we found an RT benefit for high-prevalence targets. They were found more quickly than low-prevalence targets; 2) In passive RSVP search, the LPE persisted, even though participants never had to terminate search on their own (responses were made following presentation of the entire stream); 3) Eye-tracking analyses showed that fast RTs to the high-prevalence item were explained by better attentional guidance, as indicated by scan-path ratios, and faster perceptual decision-making (indexed by post-fixation RTs); and 4) Even when people look directly at low-prevalence targets, they failed to report them on between 12% and 29% of trials (depending on the experiment). These results strongly argue for an attentional account of the LPE. Low-prevalence misses appear to represent failures of attention, rather than early search termination or motor errors.

25.26, *6:30 pm* **Stop & think: Looking into a scotoma** Christian P. Janssen[1](cjanssen@ski.org), Preeti Verghese[1]; [1]The Smith-Kettlewell Eye Research Institute

Introduction: Individuals with macular degeneration are often unaware of information they miss in their central vision, likely due to perceptual filling in. In theory, making saccades into the scotoma can compensate for

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this. To determine the feasibility of this approach, we first tested whether normally sighted controls could direct saccades into an artificial scotoma. Method: Four observers made a same/different judgment on pairs of stimuli drawn from 24 selected silhouettes in the Snodgrass & Vanderwart image set (1980) and presented on opposite sides 8.5 degrees from fixation. The visible stimulus appeared gradually over 250 msec to avoid abrupt transients associated with the anti-saccade task. A peripheral artificial scotoma hid the other stimulus until a saccade was made towards it. Observers had up to 2 s to make a saccade, but the display was extinguished 300 msec after the first saccade. In Experiment 1 stimuli within a block were on the same axis spanning fixation, along either a cardinal or oblique axis. In experiment 2, cardinal and oblique axes were intermixed. Axis angles ranged between 0 and 360 degrees, in 45 degrees increments. Results: Three observers successfully directed their gaze into the scotoma and uncovered the hidden stimulus. The fourth observer did so on slightly more than half of the trials. Saccade latencies were longer when saccades targeted the scotoma, compared to when they targeted the visible stimulus, particularly when target axes were interleaved. There was no significant latency difference between targets on cardinal and oblique axes. Conclusion: Our results demonstrate that normally sighted observers can look into the blank region of an artificial scotoma, even when a distracting target is present. This oculomotor strategy is similar to an anti-saccade and requires a delayed and more deliberate saccade plan, especially when the location of the missing information is unknown in advance.

Acknowledgement: Pacific Vision Foundation grant to CPJ and PV, Rachel C. Atkinson award to CPJ, R01 EY022394 to PV

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Development: Lifespan

Saturday, May 17, 2:45 - 6:45 pm
Poster Session, Jacaranda Hall

26.301 The Reliability of Infant Accommodation and Vergence Responses in the Absence of Blur or Disparity Cues

T. Rowan Candy[1](rcandy@indiana.edu), Erin Babinsky[1], Tawna L. Roberts[2], Vivian Manh[3]; [1]Optometry, Indiana University, [2]Optometry, University of Houston, [3]Ophthalmology, University of Washington

Postnatal development of the visual system depends on retinal image quality and correspondence. These are defined by an infant's ability to accommodate and align their eyes to targets in a dynamic 3D environment. Numerous factors impact development of these coupled responses including immaturities in sensory sensitivity to blur and disparity, the primary cues to accommodation and vergence. Infants' accommodation responses in the absence of disparity cues (condition 1), and vergence responses in the absence of blur feedback (condition 2) were determined, to understand the relative reliability of the two motor responses. Methods: Accommodation and vergence responses were recorded simultaneously, at 25Hz, using the MCS PowerRefractor (photorefraction and Purkinje image eye tracking). 95 infants recruited and tested between 3 & 5 months of age, were tested again between 7 & 9 months of age. They viewed a 7cm square animated cartoon moving repeatedly on a motorized track between 80cm (1.25D) and 33cm (3D). In condition 1, the right eye was occluded with a near-IR filter eliminating disparity cues (while recording from both eyes). In condition 2, the cartoon screen was covered with a spatially low-pass filter, with a 2D Difference of Gaussian (DOG) printed on it to remove blur feedback. Results: Raw responses were filtered to remove outliers, based on manufacturer's recommendations and physiological plausibility. Correlations between responses and the stimulus profile were then calculated. At both ages, the vergence response in the absence of blur feedback was more highly correlated with the stimulus than accommodation responses in the absence of disparity cues (mean correlation: 3-5m = 0.27 (SD+/- 0.21) vs 0.02 (+/-0.23), $p<0.001$, 7-9m = 0.15 (SD+/-0.23) vs 0.01 (+/-0.24), $p<0.001$). Discussion: Although quite variable, vergence responses in the absence of blur feedback to accommodation were driven more reliably than accommodation in the absence of disparity, suggesting increased senstivity or reduced tolerance to error in vergence.

Acknowledgement: R01 EY014460 , P30 EY019008

26.302 Effects of External Noise on Contrast Sensitivity for Intact and Scrambled Faces in Infants

Karen Dobkins[1](kdobkins@ucsd.edu), Emily Blumenthal[1], Melissa McIntire[1], Suzanne McDonald[1], Holly Bergen[1]; [1]Department of Psychology, University of California San Diego

Introduction: Previous EEG studies in infants have shown that intrinsic noise levels are much higher in neonates than in adults, demonstrated by the finding that the amount of external noise needed to affect grating contrast sensitivity (measured by sweep VEPs to gratings) is significantly greater in infants (Skoczenski and Norcia, 1997). Here, we addressed the question of intrinsic noise and face contrast sensitivity using a behavioral paradigm, and compared effects between intact vs. scrambled faces. Methods: Using forced-choice preferential looking (FPL) in 3-month-olds ($n = 12$) and 6-month-olds ($n = 14$), two measures were obtained for each subject, for either intact or scrambled faces. (1) Contrast Sensitivity (CS): We first obtained CS to intact or scrambled faces, using stimuli that were 17 by 22°, centered 16.5° from center. Across trials, contrast varied between 1 and 22 RMS contrast. (2) Noise Sensitivity (NS): In the second stage, we measured the amount of noise needed to bring subject performance for detecting the "target" stimulus (intact or scrambled faces) down to 75% correct. For each subject, the target stimulus was presented at 4-fold their contrast threshold from part (1) so that visibility was equated across all subjects. Noise consisted of randomly positioned light and dark squares (0.6° square) added to the target stimuli (noise contrast varied from 1 and 30 RMS contrast). Results: For part (1), CS increased between 3- and 6-months for intact ($p <0.01$) but not scrambled faces ($p = 0.49$, ns). For part (2): NS was roughly constant between 3- and 6-months for both intact ($p = 0.21$, ns) and scrambled faces ($p = 0.94$, ns). Conclusions: These preliminary results suggest that the increase in contrast sensitivity to faces in the first six months of life is not a result of age-related decreases in intrinsic noise within face detection mechanisms.

26.303 Infants' visual fixations to novel objects after individual-level training

Eswen Fava[1](efava@psych.umass.edu), Lisa Scott[1]; [1]Department of Psychology, College of Natural Sciences, University of Massachusetts Amherst

Infants rapidly tune their face processing abilities during the first year of life. This developmental phenomenon has been called "perceptual narrowing" and results in a decline in ability to tell the difference between faces within less frequently encountered face groups. However, if infants are given individual-level face training (i.e., they learn the proper names for each face), they maintain their ability to discriminate between otherwise not salient exemplars (e.g., monkey faces). In contrast, infants trained with category-level labels (e.g., "monkey") exhibit the same decline seen without training. It is currently unclear whether or not the process of perceptual narrowing can be applied to object processing and whether attention or visual strategy use changes with individual-level training. The present investigation trained infants from 6- to 9-months of age with unfamiliar novel objects using individual or category level labels presented in a storybook. Before and after training, infants viewed pictures of untrained novel objects, as well as novel human and monkey faces while fixation durations were recorded with an eye-tracker (SR EyeLink). A 9-month-old untrained control group was also tested to determine general effects of training. Overall, infants fixated the objects significantly longer than the faces. After training, only infants trained at the individual-level decreased increased their looking time duration, relative to pre-training. In addition, infants trained at the individual-level looked significantly longer toward the right side of untrained exemplars within the trained novel object categories. No such looking bias was found for infants trained at the category level or infants in the control group. These results suggest that learning novel objects at the individual level leads to increased attention, indicating generalization of learning, after individual-level but not category-level training. In addition, the right-side looking bias may indicate more lateralized processing of stimuli when trained with individual-level labels.

Acknowledgement: National Science Foundation Career Award for Lisa Scott (BCS=1056805)

26.304 An analysis of optic flow observed by infants during natural activities

Florian Raudies[1](fraudies@bu.edu), Rick Gilmore[2]; [1]Center for Computational Neuroscience and Neural Technology, Boston University, 677 Beacon Street, Boston MA, 02215 USA, [2]Department of Psychology, Pennsylvania State University, University Park, PA 16802 USA

A central question in vision concerns how the statistics of natural environments shape perception. There is a growing body of evidence about how static image statistics shape perceptual processing, but relatively little is known about the statistics of motion. Self-motion generates optic flow with patterns and speeds that differ based on the motion of the body, trunk, head, or eye, the motion type (translation or rotation), and scene geometry. The statistics of optic flow due to self-motion may change across age due to development in motor abilities, head and body posture, and the relative frequency of passive versus active locomotion. Here, we assess head-centered optic flow observed by infants across a wide range of ages, postures, and scenes (e.g. indoors/outdoors) and compare the frequency of optic flow patterns and overall visual speeds in each setting. Methods. Infants wore head-mounted cameras while performing simple natural activities: Walking, sitting, playing, interacting with caregivers, riding in a stroller, or being carried in a front-facing baby carrier. We estimated optic flow from short (~30 sec) segments of the recorded videos. We used the estimated optic flow to estimate the relative frequency of optic flow patterns and visual image speeds. Results. Optic flow patterns differ between infants engaged in passive locomotion compared with those moving themselves. Infants in passive locomotion view translational flow patterns more often than actively moving infants. Further, infants who are not coupled to an adult in locomotion view a wider and slower distribution of flow speeds. Thus, the statistics of optic flow differ depending on active versus passive self-motion. Conclusion. The relative frequency of experienced flow patterns and speeds may change substantially across development. More generally, state-of-the art optic flow estimators permit a detailed analysis of the optic flow statistics of dynamic natural visual experience during development.

Acknowledgement: Supported by NSF BCS-1147440, NSF SMA-0835976, NSF OCI–0821527, and Linda Smith's lab by providing the videos.

26.305 **Anticipatory Looking Paradigm for Visual Categorization in Infants**
Samuel Rivera[1](rivera.162@osu.edu), Vladimir Sloutsky[1]; [1]Department of Psychology, The Ohio State University

Visual categorization, the ability to group objects that are visually alike, is an essential aspect of cognition that facilitates recognition, inference, and generalization from infancy onward. Several methods test the development of this ability, most notably generalized imitation, and habituation. Imitation-based methods disadvantage younger infants with less developed motor control, making habituation the standard approach. Habituation relies on the tendency for infants to look away when bored with a stimulus, with shorter looking times interpreted as reflecting greater familiarity with the stimulus. Thus, infant category learners decrease looking when presented with several examples of a particular category, and increase looking to a new object class. We offer an alternative paradigm based on the anticipatory looking procedure of McMurray and Aslin (McMurray & Aslin, 2004), which demonstrated that infants anticipate the repeated emergence of an object from behind an occluder. We extend the idea to test infants' ability to learn categories.In our design, we present infants with a large tube that contains a centralized entry point at the top and two separate left and right exits at the bottom. Over learning, infant participants learn to associate each of two different categories with specific exit points, as represented by shorter latencies and anticipatory looking to the correct exit tube. The advantage of such an approach is that unlike habituation, each familiarization trial tests category understanding. In our study, 18 infants from 5-24 months learned two perceptually similar artificial categories. 83% showed shorter latencies to fixate the emerging object on trials 5-8 versus trials 1-4. Furthermore, the percentage of correct anticipatory looks (<150ms after initial emergence from tube) increased from 20% to 31%. These results demonstrate the utility of the approach for evaluating categorization ability in infants.

26.306 **Development of Category-Selective Domains in Infant Macaque Inferotemporal Cortex**
Margaret Livingstone[1](mlivingstone@hms.harvard.edu), Justin Vincent[1], Tristram Savage[1], Krishna Srihasam[1]; [1]Department of Neurobiology, Harvard Medical Schoo

In humans and in monkeys inferotemporal cortex, the object recognition part of the visual pathway, is divided up into domains specialized for processing specific object categories, such as faces, text, places, and body parts. It is not known how innate programs and early experience interact to generate this parcellation. To illuminate this question we did functional MRI on infant and juvenile macaques. We have developed techniques for safely and non-invasively doing functional MRI in alert infant macaques. We have scanned monkeys as early as 3 months of age and thereafter as IT develops. We find a rostro-caudal gradient of development of visual responsiveness. We further find that in the youngest monkeys we have scanned (3 months & 6 months of age) IT initially does not show clear segregation into category-selective domains but does show robust retinotopic organization. Category-selective domains emerge during the second year of life. In two monkeys the earliest appearing domain is the anteriormost face patch.

Acknowledgement: NIH EY16187

26.307 **Cortical Correlates of Global Form and Motion in Infant Macaque Monkeys: A Comparison of hdEEG and Behavioral Responses**
Angela Voyles[1](acv246@nyu.edu), Anthony M. Norcia[2], Lynne Kiorpes[1]; [1]NYU Center for Neural Science, [2]Stanford University

Adult primates easily integrate global form and motion cues over space or space/time, but this ability is not present at birth and slowly develops postnatally. To understand how development of global perception might be related to postnatal cortical maturation, we examined how neural responses, as reflected by high-density visually evoked potentials (VEPs), changed with age. We then compared those neural responses to behavioral capabilities in the same individuals. We tested three infant macaque monkeys (Macaca nemestrina) longitudinally between the ages of 6 and 40 weeks. Sensitivity to global form was evaluated as a difference in response to a coherent Glass pattern versus an incoherent random dipole stimulus; global motion sensitivity was tested using random dot kinematograms (RDKs) of 100% versus 0% coherence. VEP signals were recorded with a 27-electrode custom-designed cap. A differential response to coherent versus incoherent stimuli gave rise to a nonzero first harmonic of the VEP; the extent of the difference was reflected in the first harmonic's amplitude. Behavioral sensitivity to the same patterns was measured using two-alternative forced-choice psychophysics; coherence threshold for discrimination was measured as a function of age. The pattern of neural results paralleled the behavioral data for both global form and global motion stimuli. Glass pattern and RDK stimuli that elicited behaviorally measurable responses also gave rise to increased first harmonic VEP responses (1-tailed t-test, $p < .05$ for form; $p < .01$ for motion). First harmonic amplitudes also seemed to increase with age, as behavioral capabilities continued to improve (Pearson correlation, $p < .05$ for form; $p = .056$ for motion). Our behavioral results are consistent with the developmental program seen previously in young monkeys. The parallel pattern of VEP development suggests that this measure reflects the maturation of underlying cortical mechanisms required for the perception of global form and motion.

Acknowledgement: EY021894, EY05864, EY01790

26.308 **Developing Time-Based Visual Selection: The Preview Task in Children**
Zorana Zupan[1](z.zupan@warwick.ac.uk), Elisabeth Blagrove[1], Derrick Watson[1]; [1]Department of Psychology, University of Warwick

Visual search is facilitated when half of the distractors are presented in advance and can be actively inhibited – the preview benefit (Watson & Humphreys, 1997). We investigated the developmental course of this top-down inhibitory control by measuring the preview benefit in children of middle to late childhood. In order to evaluate whether this process followed a similar trajectory to more traditional measures of top-down cognitive control, children also completed executive function (EF) tasks assessing switching, inhibition (Shape-School Extended; Ellefson & Espy, 2005), and verbal/ spatial memory tests (Working Memory Test Battery for Children; Pickering & Gathercole, 2001). Our results show that a preview benefit is observed at small display sizes for 6 and 8 year old children, but that it is not present at larger display sizes. The preview benefit emerges fully in 12 year-old children at all display sizes. Children of all age groups searched baseline single feature, conjunction and preview search tasks more slowly than adults and produced more errors. Both the response times and the number of errors decreased with age. None of the EF measures correlated with the strength of the preview benefit. This suggests that: a) top-down inhibition does not develop until late childhood, b) preview search at small display sizes is mediated by different processes than at large display sizes, and c) top-down inhibition applied in time-based visual selection is different from inhibition during search, and from inhibition measured by current EF tasks. Overall, these results show that the attentional mechanisms involved in inhibitory time-based selection develop over the age range of 8 to 12 years.

26.309 **Effects of Eccentricity on Infants' Change Preference in a VSTM Task**
Mee-Kyoung Kwon[1](mkwon@ucdavis.edu), Steven Luck[1], Lisa Oakes[1]; [1]Department of Psychology, UC Davis

Infants' visual short-term memory (VSTM) is typically assessed using the simultaneous streams change detection task (Ross-Sheehy et al., 2003). In this task, infants are presented with two stimulus streams, side-by-side, in which one or more colored squares appear briefly (for 500 ms), disappear briefly (for 300 ms), and then reappear briefly (for 500 ms); this cycle repeats continuously for the duration of the trials. One of the two streams is a changing stream, in which one randomly chosen item changes color on each cycle, and the other is a non-changing stream, in which the objects remain unchanged from cycle to cycle. VSTM ability is inferred from infants' preference for the changing stream. Exhibiting such a preference requires that infants perceive the two streams as separate and attend to the changing stream while inhibiting attention to the (distracting) non-changing stream. The eccentricity of the display may contribute to both processes, and therefore may have an impact on infants' ability to detect and prefer the changing stream. We examined the effect of eccentricity on 64 6-month-old infants' change detection at set sizes 1 and 2. The center-to-center distance of the two streams was either 44˚ or 27˚. We found that infants exhibited a significant change preference only for the combination of set size 1 and 44° of eccentricity. No significant change preference was observed at set size 2 for either eccentricity, and no significant change preference was observed for either set size at 27° eccentricity. Thus, 6-month-old infants' ability to exhibit a preference for changing streams can be disrupted by decreasing the distance between stimulus streams. As smaller eccentricities, infants may perceive the two arrays together, or have difficulty inhibiting attention to the non-changing stream.

26.310 **The Claim that Pre-School Children are Insensitive to Nonaccidental vs. Metric Shape Properties Challenged by Biologically-Based Shape Scaling**
Ori Amir[1](oamir@usc.edu), Irving Biederman[1,2]; [1]Psychology Department, University of Southern California, [2]Neuroscience Program, University of Southern California

Nonaccidental properties (NAPs) are image properties that are invariant over orientation in depth, e.g., straight vs. curved, and are distinguished from metric properties (MPs), e.g., degree of curvature, that change continuously with variations in depth. The reliance on NAPs allows facile identification of objects at novel orientations. Greater sensitivity to NAPs than MPs has been demonstrated in adults (both in developed and undeveloped cultures), infants, and non-human organisms, i.e., pigeons, macaque IT cells. Two studies, Abecassis et al (2001) and Sera and Millett (2011), however, concluded that pre-school children had not yet developed increased sensitivity to NAPs. These studies reported that adults—but not young children--were more likely to generalize a name for a novel object (a "wug") with, say, a slight degree of curvature of the axis of a part (a geon), to another object differing in an MP (greater curvature) compared to one that differed in a NAP (straight), a result that led the authors to infer a relatively late onset for NAP sensitivity. To compare sensitivity to NAPs vs. MPs, the physical differences between a standard (the "wug") and the NAP and MP variants must be equated in terms of the physical coding of the earlier stages of the visual system. Here we show, with a model that computes shape similarity based on V1 simple cells, that such differences (from the wug) were greater for the MP than the NAP stimuli, thus likely counteracting the greater sensitivity to NAPs. This inference was supported by an independent study in which every preschool child showed greater sensitivity to NAPs than MPs when the two kinds of shape variation were equated accorded to the V1 model of shape similarity. Taken together, NAP sensitivity and the V1 model can explain 97% of adults' and 90% of childrens' classification choices.

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26.311 **Age-related differences in visuo-haptic integration** Jutta Billino[1](jutta.billino@psychol.uni-giessen.de), Knut Drewing[1]; [1]Experimental Psychology, Justus-Liebig-Universität Giessen

Over the last years demographic changes have fostered research on functional aging. Age-related decline within individual sensory systems is well documented, but there is still a lack of understanding how multisensory processing is altered across life span. We studied age effects on visuo-haptic length judgments and evaluated optimality of multisensory integration. In a two-interval forced choice task 24 young adults (20-25 years) and 25 senior adults (69-77 years) compared the length of standard stimuli to a set of comparison stimuli. Standard stimuli were presented to vision, haptics, or to both senses. In the visuo-haptic condition intersensory conflicts were introduced by magnifying and reducing optical lenses. Comparison stimuli were always explored in the haptic modality alone. We determined psychometric functions for each modality condition. Age groups did not differ in their points of subjective equality (PSE) in any condition. Visuo-haptic PSEs lay in-between the results for the unisensory conditions indicating multisensory combination in both age groups. Discrimination thresholds, i.e. just noticeable differences (JND), showed significant sensitivity differences only in the visual modality. Based on measured PSEs and JNDS we calculated the weights given to each modality and estimated optimal weights suggested by the Maximum-Likelihood-Model. We found that young and senior adults integrated visuo-haptic signals quite similarly with visual information contributing about 30% to length judgments. Comparison between measured and estimated weights, however, revealed greater deviation from optimal integration in young adults than in senior adults (-28% vs. +3%, respectively). Our results provide evidence that although both age groups integrate visual and haptic signals, senior adults exploit available sensory information far more efficiently than younger adults. We suggest that optimal weighting of multisensory signals might support successful compensation for sensory decline during aging.

26.312 **Without social cues it's male: Children perceive amorphous drawing of adults as male, but less so in social contexts** Aenne Brielmann[1](aenne.brielmann@uni-konstanz.de), Margarita Stolarova[1,2]; [1]Departement of Psychology and Zukunftskolleg, University of Konstanz, [2]Faculty of Society and Economics, Rhine-Waal University of Applied Sciences

People's strong tendency to assign male gender to neutrally described persons has been termed the people = male bias. We aimed to assess whether this effect can be elicited using amorphous visual stimuli instead of verbal descriptions and whether it is already evident in childhood. We presented 53 children (4 to 12 yrs., 27 boys) with black-and-white amorphous drawings of humans and asked them whether the adult depicted was a man or a woman. The option to choose "I don't know" was also provided. In order to assess whether social contexts influenced children's gender attributions (as has been previously reported for adults) we placed the same amorphous humans in three different contexts: 1) the adult was depicted alone, 2) the adult was passively involved in a social situation with a child and 3) the adult was actively helping a child. Children showed a clear tendency to assign male gender to the amorphous adults across all context variations; this was equally true for boys and for girls. However, when the adult was shown in a social context the proportion of male gender attributions was lower compared to the condition without social context. The older the children were, the more likely they were to attribute female gender to a higher proportion of amorphous figures across all contexts. Median response times were higher for "female" ratings, indicating that this decision was associated with greater cognitive effort. Our results show that a strong bias towards attributing male gender to visually presented amorphous figures is evident already in childhood and that it somewhat decreases with age. For children, just as it has been demonstrated for adults, social contexts lead to a larger proportion of female gender attributions. These results encourage future research to include developmental aspects for explaining the mechanisms underlying gender perception and stereotypes.

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26.313 **Visual search performance and IQ in 2-year-olds** Annalisa Groth[1](annalisagroth@gmail.com), Sylvia Guillory[1], Erik Blaser[1], Zsuzsa Kaldy[1]; [1]Department of Psychology, UMass Boston

Background: Performance on visual search tasks reflect the ability to attend to a task while successfully ignoring distractions. Research on the link between visual search ability and general intelligence have so far yielded mixed results (e.g. Rezazadeh et al., 2011; Huang et al., 2012) and there has been very little research that investigated this relationship early in life. Here we examined this link in 2-year-old typically developing toddlers. Methods: 30 full-term, healthy children (14 females, mean age: 27.7 months) participated. We developed a no-instruction version of the classic visual search paradigm specifically designed for toddlers. Stimuli consisted of single-feature (color [red/blue] and shape [circle/rectangle]; set sizes: 9, 13) and feature-conjunction trials (set sizes: 5, 9, 13) in mixed blocks. Search displays were presented for 4 s, then the target (always a red circle) rotated for 3 s; acting as feedback and reward. A Tobii T120 eye tracker was used to record eye movements. Our dependent measure was success at fixating the target within the 4 s search period. Following the visual search task, all participants were assessed for general intelligence using the Mullen Scales of Early Learning (Mullen, 1989), a standard early measure of mental age. Results: As expected, success rates in the feature-conjunction trials (but not in the single-feature trials) decreased with set size. Additionally, toddlers with above median IQ had significantly higher success rates in feature-conjunction trials than those below the median ($p = 0.027$), this difference being most pronounced in the highest set size (13 items) trials. Conclusion: These findings suggest that visual search skills may be related to intelligence in children as young as 2 years of age. Future studies may explore whether this effect is mediated by a general attention factor.

Acknowledgement: This project was supported by the UMass President's Science & Technology Award and a grant from the Simons Foundation under the auspices of the Simons Center for the Social Brain at MIT (Grant# SCSBMIT) awarded to ZK and EB.

26.314 **Development of audiovisual integration in central and peripheral vision** Yi-Chuan Chen[1](chenyic@mcmaster.ca), Terri L. Lewis[1], David I. Shore[1], Daphne Maurer[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University, Canada

We measured developmental changes (7-, 9-, and 11-year-olds, and adults) in audiovisual integration utilizing the visual fission and fusion illusions induced by sounds. In the fission illusion, a single flash is perceived as two flashes when accompanied by two beeps. In the fusion illusion, two flashes are perceived as a single flash when accompanied by a single beep. The flashes were presented in the centre or 10° in the periphery. The results revealed different developmental changes for the fission and fusion illusions in the centre and periphery. In the centre, fission and fusion decreased with age ($p <.05$, post-hoc tests revealed that the magnitude was smaller in adults than 7- and 9-year-olds, $ps <.05$), and there was no difference in the pattern for the two illusions (no main effect and no interaction, $ps > .33$). In contrast, in the periphery, fission was larger than fusion ($p <.001$), and this difference increased with age ($p <.05$, post-hoc tests revealed that the difference was larger in adults than 7- and 9-year-olds, $ps <.05$); however, there was only a marginal effect of age on magnitude of the illusions ($p = .06$). A further analysis based on signal detection theory demonstrated that these developmental changes in central and peripheral vision were partly caused by changes in sensitivity (d') to the flashes. These results suggest that developmental trajectories of audiovisual integration in the centre and periphery are different, and that, with age, peripheral vision becomes more susceptible than central vision to different types of audiovisual integration (i.e., fission vs. fusion). The results also demonstrate that audiovisual integration in central and peripheral vision does not become adult-like until 11 years of age, at least as measured by these two illusions.

Acknowledgement: This study is supported by James S. McDonnell Foundation.

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26.315 Reduced Perceptual Narrowing in Synaesthesia: Discrimination of Native and Non-native Stimuli

Julian K. Ghloum[1](ghloumjk@mcmaster.ca), Laura C. Gibson[1], Marcus Watson[2], Kathleen Akins[3], Lawrence Chen[2], James T. Enns[2], Janet F. Werker[2], Daphne Maurer[1]; [1]Psychology, Neuroscience & Behaviour, McMaster University, [2]Department of Psychology, University of British Columbia, [3]Department of Philosophy, Simon-Fraser University

Synaesthesia is a neurological condition in which input to one sense causes an automatic and consistent extra percept, often in another sense (e.g., C sharp elicits a pale yellow). Synaesthesia is hypothesized to arise, at least in part, from less-than-normal neural pruning of the exuberant connections in sensory cortical areas during infancy (reviewed in Maurer, Gibson, & Spector, 2013). Perceptual narrowing describes an infants' increasing skill at differentiating among stimuli within native categories (e.g., upright own-race human faces) and the simultaneous loss of a more general ability to discriminate stimuli from non-native categories (e.g., other-race, other-species, inverted faces) (reviewed in Maurer & Werker, in press). Perceptual narrowing is thought to reflect experience-dependent pruning of initially exuberant neural connections and typically occurs by 9 months of age. Here we tested the hypothesis that adult synaesthetes show evidence of less perceptual narrowing, i.e., whether adult synaesthetes are better than non-synaesthetic adults in discriminating items from non-native categories. Participants performed a speeded simultaneous matching-to-sample task on upright human and chimp faces that differed only in spacing of the internal features. The task involved matching one of the two faces at the bottom of the screen with the face at the top of the screen. A subset of participants performed the same task with inverted human faces. Planned comparisons revealed synaesthetes (n=41) were more accurate than non-synaesthetes (n=40) in discriminating among chimp faces (t(79)=2.7, p=.004), with no difference for upright human faces (t(79)=1.108, p=.135). In addition, synaesthetes (n=19) were more accurate than non-synaesthetes (n=28) in discriminating among inverted human faces (t(45)=2.726, p=.005). The results suggest that synaesthetes undergo less perceptual narrowing during development, providing behavioral evidence for a developmental mechanism underlying synaesthesia.

26.316 Neural correlates of own- and other-race face recognition in preschoolers: A functional near-infrared spectroscopy (fNIRS) study

Xiao Pan Ding[1](dingxiaopan@gmail.com), Genyue Fu[1], Kang Lee[2]; [1]Zhejiang Normal University, [2]University of Toronto

Previous studies revealed a neural other-race effect (NORE) paralleling the behavioral other-race effect, suggesting that adults' asymmetrical experience with own- and other-race faces have a direct impact not only on their behavior but also on neural responses. However, the developmental origin of the neural other-race effect is still unknown. The present study used the functional Near-infrared Spectroscopy (fNIRS) methodology to investigate the neural correlates of preschoolers' own- and other-race face processing. An old-new paradigm was used to assess preschooler's recognition ability of own- and other-race faces (N=67, Age: 4.08 to 6.50 Years). FNIRS data revealed that own-race faces elicited significantly greater [oxy-Hb] changes than other-race faces in the left middle frontal gyrus (left MFG, BA10, 46) and the left middle occipital gyrus (left MOG, V2). The [oxy-Hb] activity differences between own- and other-race faces, or the NORE was significantly positively correlated with age in the left MFG, but negatively correlated with age in the left MOG. Moreover, these areas had strong functional connectivity with a large swath of the cortical regions in terms of the NORE. These results taken together suggest that similar to school aged children and adults, preschoolers devote different amounts of neural resources to processing own- and other-race faces. But the size of their neural other-race effect and associated functional regional connectivity undergo developmental changes.

26.317 A Horse of a different color: Early visual environments in an Indian community

Swapnaa Jayaraman[1](swapnaa@indiana.edu), Linda Smith[1]; [1]Psychological and Brain Sciences Department, Indiana University

Properties of our visual system are deeply related to visual properties of our environments. Early visual environments in particular have a significant influence on the development of the visual system. To understand the nature of early visual input available to humans, researchers have captured natural environments from the perspective of young infants using head-mounted cameras [Aslin, 2009; Jayaraman et al, 2013; Sugden et al, 2013]. These environments typically characterize input available to infants in a specific context - middle class North American homes and their surroundings. However, infants' environments are arguably different across various socio-economic and cultural contexts. In this study, we captured the natural visual environments of twelve infants aged 0-14 months from a fisherman community of low socio-economic status in Chennai, India. We compared the images captured by these infants with images from age-matched infants from middle class homes in Bloomington, IN (USA). To ensure directly comparable images we used the same cap-mounted camera setup on both sets of participants. The resulting images reveal that visual environments of Indian infants are indeed very different from those of US American infants on several measures. Preliminary examination suggests that images from homes in India have lower luminance and higher contrast than those in the US. The range of hues is also narrower in the Indian images. These differences could be a function of geographic (quality of natural light), economic (availability of artificial lighting), and socio-cultural (aesthetic preferences) factors. While the factors that cause these differences are interesting in their own right, the implications of these differences are profound. Basic attributes of early input, such as luminance and contrast levels, are known to play a major role in the development of the visual system. If these attributes differ could that imply significant differences in the development of visual systems across populations?

26.318 Aging and the effect of size information on the control of braking

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Previous studies have found observers used tau-dot to regulate braking (Yilmaz & Warren, 1995; Fajen, 2005). Braking performance was also affected by global optical flow and edge rate information (Fajen, 2005). Previously we examined age-related differences in the use of ground texture information in braking regulation (Bian & Andersen, 2013, VSS). In the current study we examined age-related differences in the use of size information in regulating braking. Observers included twelve younger (mean age = 21.6) and twelve older adults (mean age = 73.1). On each trial, observers viewed computer generated 3-D scenes (visual angle = 106.4° × 73.9°) simulating driving on a roadway towards three stop signs at a constant speed. During the first 5 seconds, the observers did not have control over the brake. Five seconds later, observers heard a warning tone indicating the control input was allowed. Their task was to apply smooth and continuous braking and stop as close as possible to the stop signs. The initial time-to-contact (3s, 3.5s, or 4.0s), initial speed (40kmph, 60kmph, or 80kmph), texture on the ground (no texture or 32×64 checkerboard) and size of the stop signs (0.2m or 0.6m each side) were manipulated. The texture was blocked and counterbalanced across observers in each age group. The mean stop distance relative to the stop signs, standard deviation of stop distance, crash rate and distribution of tau-dot were collected. We found that older observers had larger mean stop distances and lower crash rates when large stop signs were presented. Younger observers, however, had higher crash rates when large stop signs were presented. In addition, regulation of tau-dot varied as a function of size for younger but not older observers. These results, taken together, suggest that older observers may use size information differently for determining distance than younger observers in braking regulation.

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26.319 Colour discriminability and flicker sensitivity measures improve detection rates of early Age-related Macular Degeneration.

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Aim: Age-related Macular Degeneration (AMD) is the leading cause of irreversible blindness in the aged population in developed countries. Despite advances in treatment for early-stage AMD, standard clinical tests to diagnose AMD have poor sensitivity. The aim of this study was to compare the sensitivity of the current standard diagnostic test, i.e., LogMAR visual acuity, to other psychophysical tests of visual function, to determine what combination of tests can improve detection rates of early AMD. Methods: A total of 45 normal and 30 early-stage AMD subjects (with varying degrees of maculopathy) were investigated. Monocular assessment of visual acuity (LogMAR), chromatic discriminability (Colour Assessment and Diagnosis test or CAD test)1 and small field, flicker sensitivity (to 20Hz) tests were conducted under photopic and mesopic viewing conditions. Results: A multilinear regression analysis was conducted. Analysis revealed that photopic yellow-blue (YB) chromatic sensitivity alone, improved early-stage AMD detection rates by 11.3%. When combined with mesopic flicker sensitivity data the detection rate increased by a further 4%. ROC analysis revealed a statistically significant difference (p=0.0001) between photopic yellow- blue chromatic sensitivity and LogMAR visual acuity measurements, indicating that psychophysical assessment of YB chromatic discrimination is a more sensitive diagnostic test than the current standard clinical tool. Conclusions: Comparison of visual acuity, flicker sensitivity and chromatic discriminability suggest that photopic YB chromatic

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sensitivity is the most sensitive measure in detecting early AMD retinal changes and potentially could be used to support and / or replace current diagnostic tests. 1 Rodriguez-Carmona, M., Harlow, A. J., Walker, G. and Barbur, J. L. (2005). The variability of normal trichromatic vision and the establishment of the 'normal' range. Proceed- ings of 10th Congress of the International Colour Association, Granada (Granada, 2005), pp. 979–982

Perceptual organization: Segmentation, shapes and objects

Saturday, May 17, 2:45 - 6:45 pm
Poster Session, Jacaranda Hall

26.320 **Impaired perception of rigidity induced by the amodal completion of 3D structures in active and passive vision** Carlo Fantoni[1,2](cfantoni@units.it), Walter Gerbino[1], Elena Milani[1], Fulvio Domini[2,3]; [1]Department of Life Sciences, University of Trieste, [2]Center for Neuroscience and Cognitive Systems@UniTn, Istituto Italiano di Tecnologia, [3]Department of Cognitive, Linguistic and Psychological Sciences, Brown University

The perceived slant difference between twisted patches is known to be reduced by partial occlusion, a phenomenon known as slant assimilation (Fantoni, Gerbino & Kellman, 2004; Liu & Shor, 2005). Fantoni, Gerbino and Kellman (2008) demonstrated that this phenomenon is diagnostic of visual approximation, a process mediating Amodal Completion (AC) of 3D structures that causes a distorted representation of image-specified parts. Approximation-based distortions were previously studied in impoverished viewing conditions (immobile observer) and with impoverished stimuli (stereoscopic patches under orthographic projections). Here, we show that similar distortions occur in more general viewing and stimulus conditions, as when the observer is naturally moving and the twisted surfaces are specified by self-generated optic flows under perspective projections. The sensitivity to discriminate between rigid and non-rigid 3D structures was impaired when the twisted patches appeared as the unoccluded parts of a smooth surface partially hidden by a foreground frontoparallel surface, relative to cases in which they were perceived as separated patches, either in the absence of the foreground occluding surface (Experiment 1) or with the occluding surface in the background (Experiment 2). The exact same biases were also found for passive observers, who experienced from a static vantage point the same optic flows generated during active viewing. Results are compatible with a Bayesian model that disregards egomotion information and selects a reliable prior for stationarity/rigidity in presence but not in absence of amodal completion. Results are incompatible with a model predicting that image encoding is biased towards slant assimilation in presence of AC. This calls for an update of the current notion of visual approximation in AC.

26.321 **Local Perturbations to a Global Radial Frequency Masker Alleviate Lateral Masking Effects** Michael Slugocki[1](slugocm@mcmaster.ca), Allison Sekuler[1], Patrick Bennett[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University

Radial Frequency (RF) contours, generated through the sinusoidal modulation of the radius of a circle, are a useful tool to study the processes involved in shape perception. Previous research examining RF contour detection suggests that low and high RF contours are processed by separate global and local shape detection mechanisms, respectively (Bell et al., 2007). If the processes responsible for global and local RF detection do not interact, then a lateral mask consisting of a combination of low and high RF contours should interfere with the detection of a low RF contour at least as much as a low RF contour mask alone. To test this prediction, we measured detection thresholds for a low RF contour (RF5) in the presence of a control mask (RF0), a low RF mask (RF5), a high RF mask (RF25), or a compound mask (RF5+RF25) consisting of the combination of RF5 and RF25 patterns. Consistent with previous reports, two out of the three observers show significant masking with the low RF mask relative to the control and high RF mask. Critically, these two observers showed significantly less masking for the compound mask than for the low RF mask, and did not show a significant difference in masking with the compound mask relative to the control and high RF mask. The third, anomalous, observer showed relatively high levels of masking across all conditions, including the control mask. Overall, however, our results suggest that global and local shape detection mechanisms do not operate independently of one another in masking. We currently are examining the extent to which the results reveal individual differences, and how the nature of RF interactions influences masking.

26.322 **Configural superiority reduces efficiency** Alexander Bratch[1](abratch@umail.iu.edu), Aparna Srinath[1], Shawn Barr[1], William Bromfield[1], Jason Gold[1]; [1]Psychologial & Brain Sciences, Indiana University, Bloomington

The ability of human observers to recognize visual patterns can be greatly influenced by context. For example, the introduction of context to a set of features can induce a unified percept, allowing observers to classify it more quickly and accurately (a 'configural superiority' effect; Pomerantz & Portillo, 2011). But how does context specifically impact the way in which observers make use of stimulus information? We addressed this question by applying ideal observer analysis (Geisler, 1989) and response classification (Ahumada, 2002) to a pattern identification task that has been shown previously to exhibit a significant configural superiority effect (Pomerantz & Portillo, 2011). In the 'No Context' condition, four diagonal lines appeared in separate quadrants of a virtual square. One of these lines was placed at a countering angle, and the observer's task was to identify which randomly chosen quadrant contained the odd angle. In the 'Context' condition, the stimuli were identical, with the exception that two abutting line segments (one vertical and one horizontal, forming a right angle) were added in the same position to all four quadrants. Thus, the additional features were entirely redundant, but their presence induced the percept of a unitary triangle figure within the quadrant containing the odd angle. On each trial, the stimulus was embedded in Gaussian white contrast noise, which allowed us to measure human and ideal observer contrast energy identification thresholds, as well as the pixel-wise information-processing strategy adopted by observers in each condition. Although response times were faster in the presence of context, efficiency (ideal/human threshold) was actually lower when the stimulus included the redundant features. The results of the response classification analyses suggest that the lower efficiencies in the presence of context were in part due to observers' reliance on the redundant features, which contribute noise while providing no discriminative information.

26.323 **The Role of Feedback Processes in the Emergence of Visual Hallucinations** Christoph Teufel[1](crt35@cam.ac.uk), Naresh Subramaniam[1], Veronika Dobler[2], Ian Goodyer[2], Paul Fletcher[1]; [1]Brain Mapping Unit, Department of Psychiatry, University of Cambridge, [2]Developmental Psychiatry, Department of Psychiatry, University of Cambridge

Feedback influences from higher levels of information processing onto lower levels are an important aspect of current models of visual perception. This framework has not only been useful in understanding visual perception in healthy observers; it has also been hypothesized that it can provide a unified explanation of both hallucinations and delusions in psychotic patients. Here, we report the result of three experiments that examined memory-based changes in the perception of two-tone images ('Mooney images') as a model for visual hallucinations. We tested the hypothesis that the visual system of hallucination-prone individuals relies more strongly on feedback processes. In the first experiment, (i) we quantified feedback-processes in a group of At-Risk-Mental-State (ARMS) patients and matched healthy controls. We employed a psychophysical task that measured observers' sensitivity to discriminate two-tone images of objects from control images (that lacked embedded objects) with and without prior knowledge of image content. In a second experiment, (ii) the same observers participated in an fMRI study in which the neural correlates of their subjective experience of two-tone images were assessed. Finally, in a correlational study (iii) we related performance of a larger set of healthy observers in the psychophysical task to their scores on two schizotypy scales indexing aberrant perception and a delusional style of thinking. Together, the three experiments provide evidence to suggest that vision in hallucination-prone individuals is characterised by a stronger influence of prior object knowledge on perception. We discuss potential candidate systems underlying this bias in information processing and the implications for models of schizophrenic and healthy vision.

Acknowledgement: The Wellcome Trust

26.324 **Seeing and liking from the outside in: Consistent inward biases in visual perception and aesthetic preferences** Yi-Chia Chen[1](yi-chia.chen@yale.edu), Brian Scholl[1]; [1]Department of Psychology, Yale University

Perception, as represented by most vision science research, is the process of recovering the physical structure of the world from shifting patterns of retinal images. But actual visual experience nearly always transcends this characterization. An especially salient example involves the aesthetic qualities of perception: it is often impossible to see something without also liking or disliking it. It may be possible to explain some (perhaps

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small) percentage of such experiences in terms of underlying regularities of visual processing. Even when studied in this way, however, aesthetic experience is often treated as being a later, independent aspect of perception. Here, in contrast, we explore how aesthetic preferences may interact with other types of visual processing. We were inspired by the inward bias in aesthetic preferences: when an object with a salient "front" is placed near the border of a frame (say, in a photograph), observers find the image more aesthetically pleasing if the object faces inward (toward the center) vs. outward (away from the center). We employed framed stimuli that were ambiguous in terms of the direction they appeared to be facing. For example, an equilateral triangle can be seen as pointing in the direction of any of its three vertices. Our observers' percepts were influenced by the frames in a way that corresponded to the inward bias: when a triangle was placed near a frame's border, observers tended to see whichever interpretation was facing inward. The same observers also judged an unambiguous version of the figure — an otherwise matched "drop" figure — as more aesthetically pleasing when it pointed inward. This match between the inward bias in aesthetic perception and ambiguous-figure perception suggests new ways in which aesthetic factors may relate not only to what we like, but also to what we see in the first place.

26.325 **Shape distortion illusion of circles without prolonged viewing** Kenzo Sakurai[1](sakurai@mind.tohoku-gakuin.ac.jp); [1]Department of Psychology, Tohoku Gakuin University

Previous research on shape distortion illusion revealed that prolonged viewing of a circular shape in peripheral vision produces polygonal shape perception of the circle itself (Khuu, McGraw & Badcock, 2002 ECVP), and also produces a polygonal (e.g. hexagonal) afterimage (Ito, 2011). We found that the shape distortion illusion can be induced in a short period by presenting alternation of a circle and its inward gradation pattern. We measured the induction time (latency) of this distortion illusion produced by circle/gradation alternation, and compared it with the induction time produced by prolonged viewing of static circles. In experimental condition, stimuli consisted of 5 black line drawing circles placed around a central fixation cross on a white background, and they alternated with same size inward gradation patterns in which luminance increased gradually from periphery to center. The alternation rate (temporal frequency) was varied from 0.5 Hz to 8 Hz. In control condition, only static circles were presented on a screen. Observers fixed their head on a chinrest and viewed the display, and they were asked to report the induction time by pressing a response key as soon as they noticed the shape distortion. Results showed that the induction time of this distortion effect by circle/gradation alternation was shorter than that obtained from prolonged viewing of static circles at 2~4 Hz temporal frequency. These results suggest that presenting alternation of a circle and its inward gradation pattern promotes adaptation of cortical process responsive to curvatures and induces shape distortion illusion instantly.

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26.326 **Asymmetry in Perceived Shape Similarity for Novel Shapes** Patrick Garrigan[1](pgarriga@sju.edu), Katie Binns[1]; [1]Saint Joseph's University

Perceived shape similarity is central to classic problems in vision science, including object recognition and categorization. Here we consider the "transformational" approach, in which similarity is related to the perceived ease with which one shape can be transformed into another. This definition of similarity can account for asymmetries in which, e.g., shape A is perceived as more similar to shape B than shape B is to shape A. Hahn, Close, & Graf (2009) used morphing sequences of familiar objects to show that when transformations from shape A to shape B are made more salient, shape A appears more similar to shape B, but not the reverse. We demonstrate, using a shape-similarity adjustment procedure, similar asymmetries in shape perception for novel, closed, 2D contour shapes. This result shows that the previously reported asymmetries are at least partly related to generic shape perception. Specifically, they show that neither familiar shapes nor shapes with semantic associations are required to induce perceived shape similarity asymmetries. We further illustrate a general mechanism for inducing perceived shape similarity asymmetry through established perceptual and psychophysical results. In our model, shape similarity asymmetries, like those measured in our experiments, may be explained by biases in visual attention (e.g., due to increasing information at regions of high curvature; Attneave, 1954) and the nonlinear relationship between objective and perceived feature magnitude (e.g., the sublinear scaling of perceived curvature magnitude with objective curvature magnitude; Dobson, 1971). In sum, our results suggest that transformational similarity effects may be, at least in part, a consequence of within-object attention (e.g., Garrigan & Hamilton, 2013) and the perceived magnitudes of salient shape features.

26.327 **Perceived Occlusion Velocity for Fully Visible and Fragmented Shapes** Ricarda Moses[1](moses@rhrk.uni-kl.de), Tandra Ghose[1], Gennady Erlikhman[2], Philip J. Kellman[2]; [1]University of Kaiserslautern, Germany, [2]Department of Psychology, University of California, Los Angeles, USA

Background: In order to perceive coherent perceptual units, the visual system must integrate information about fragments across space and time (Palmer, Kellman & Shipley, 2006). This requires the accurate encoding of fragment velocity when they are visible and occluded. However, previous research has shown that the representation of occlusion velocity is often not veridical (DeValois & Takeuchi, 2001; Palmer & Kellman, 2013). Questions: Is perceived occlusion velocity similar for shapes that are fully visible ("Full"), spatially fragmented, or spatiotemporally fragmented? Is the misperception (if any) dependent on the duration of occlusion? Does perceived occlusion velocity depend on eye-movement patterns or vice versa? Method: In the "Full" display a red, textured oval traveled in front of two white rectangles separated by a black rectangle (occluder). The oval was invisible when it passed behind the occluder. In the spatially fragmented condition, a horizontal black bar spanning the width of the screen separated the oval into two pieces. In the spatiotemporally condition, only top or bottom half of the oval was visible on either side of the occluder. The task was to report whether the oval emerged from occlusion sooner or later than anticipated, given its constant velocity. The time that the oval was occluded was manipulated by using short, medium, or long occluder width. The perceived occlusion-velocity was calculated from the 50% point of the resulting psychometric functions. Eye-movements were also recorded. Results and Conclusions: Perceived occlusion-velocity did not differ for whole and fragmented shapes, but varied with occluder width. Remarkably, perception of occlusion velocity was not predicted by patterns of eye movements. We discuss the results in relation to previous work on occlusion velocity with differing ranges of speed and aperture separation.

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26.328 **Contextual Information Modulates Unconscious Visual Processing in Early Visual Cortex** Lihong Chen[1,2], Yi Jiang[1]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Psychology, Chinese Academy of Sciences, [2]University of Chinese Academy of Sciences, Chinese Academy of Sciences

Human visual perception is context dependent. Previous studies have demonstrated that the conscious representation of a variety of visual stimuli can be altered by contextual information. Whether and to what extent contextual modulation could also take effect on the processing of invisible stimuli is largely unknown. Here we probed this question using two types of context-dependent visual illusions (i.e., Ebbinghaus illusion and Ponzo illusion) combined with the interocular suppression paradigm. The Ebbinghaus and Ponzo illusions, though correlated with the primary visual cortex (V1), are respectively mediated by lateral connections within V1 and feedback projections from higher brain areas to V1. Here we selectively rendered the central targets of the two illusion figures invisible while leaving their surrounding inducers intact. In the Ebbinghaus illusion, we found that the central target broke from suppression sooner when surrounded by smaller relative to larger inducers. Moreover, the illusion strength predicted the suppression time difference between these conditions across participants. In the Ponzo illusion, however, the processing of the invisible target was not influenced by the contextual inducers. These results provide strong evidence that contextual information can modulate the unconscious visual processing, and such modulation occurs in the early visual processing stream independent of feedback influences.

26.329 **Looking Beyond the Means: Rapid Learning of Prime-Display Relationship in a Semantic Priming Experiment** Alisabeth Ayars[1](alisabetha@email.arizona.edu), Andrew Mojica[1], Mary A Peterson[1,2]; [1]Psychology, University of Arizona , [2]Cognitive Science, University of Arizona

Mojica & Peterson (VSS 2013) tested whether semantic priming affected figure assignment. Subjects viewed bipartite displays suggesting a familiar object on one side of a central border and reported where they saw the figure. Masked non-words (control primes) or words naming a different object than the object suggested in the display (experimental primes) appeared before displays. Words named an object in the Same Category (natural or artificial) as the object in the display (SC) for half the subjects and an object in a Different Category (DC) for the other half. SC participants saw the familiar object as figure more often (74%) than DC participants (67%), p=0.05. However, for both groups experimental and control means were equal. We investigated whether these equal means masked differential effects of experimental and control primes at different points

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during the experiment. In SC, familiar figure reports on experimental trials were originally low due to the basic-level mismatch between the prime and the object in the display yet increased to above control trials in the second half (p=.015; regression line slope = .49, p=.005). Over time, subjects likely learned to attend to superordinate category (natural/artificial) information in the prime and to devalue basic category information, ultimately resulting in semantic priming. In DC, familiar figure reports were initially low on both experimental and control trials perhaps because the mismatch between prime and display on experimental trials led subjects to devalue semantics regardless of source (prime or display). Familiar figure reports increased on both experimental and control trials (slope = .623 and .514, ps<.004) because DC subjects likely learned to revalue semantic information from the displays. Rapid learning of the relationship between primes and displays over a 64-trial experiment influenced the weighting of semantic information for figure assignment, and was required for semantic priming to emerge in SC.

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26.330 **Global Influences on Figure Assignment: The Role of the Border** Michelle Burrola[1](michelleb@email.arizona.edu), Mary A. Peterson[2]; [1]Psychology Department, University of Arizona, [2]Psychology Department, University of Arizona, Cognitive Science Program, University of Arizona

Convexity and symmetry are well-established cues to figural status. These properties were originally thought to operate locally; for example, that the convex side of any curved border was likely to be perceived as figure. Peterson and Salvagio (2008) found that convex regions were increasingly perceived as figure as the number of alternating convex and concave regions increased. These "context effects" revealed display-wide influences on figure assignment, and required homogeneously colored concave regions. Goldreich & Peterson (2012) proposed that multiple same-color concave regions could be unified into a background, thereby allowing the convex regions to be perceived as figures in front of the background. The original context effects were obtained with displays having rectangular frame-like borders. There was no reason to think frame type mattered until Mojica and Peterson (2013) tested for symmetry context effects. Originally, they used displays with articulated borders to preserve the symmetry/asymmetry of the outermost regions. Symmetry context effects were not found, but later were found when frame-like borders were used. Mojica and Peterson reasoned that articulated outer borders were perceived as intrinsic to the display and consequently prevented the interpolation of concave regions into a background, whereas rectangular borders were perceived as extrinsic to the scene and allowed amodal continuation of the background. To test the generality of frame effects, we used 2- and 6-region convexity displays with articulated borders. Consistent with the view that articulated borders prevent the emergence of context effects, convex regions were no more likely to be seen as figure in 6-region (62%) than in 2-region displays (64%), p > .80, and were significantly less likely to be seen as figure in 6-region displays with articulated borders than rectangular borders (77%), p<.03. These results show that figure-ground cues to do not operate locally.

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26.331 **Using Extremal Edge to Decouple Closeness and Shape in Figure-Ground Perception** Tandra Ghose[1](tandra@berkeley.edu), Mary A. Peterson[2]; [1]University of Kaiserslautern, Germany, [2]University of Arizona, Tucson, USA

Traditionally, the figure is defined as that side of a border that appears both shaped and closer to the viewer than the abutting side. Both Extremal-Edge (EE) and upright familiar configuration are figural cues. Ghose and Palmer (2010) showed observers displays divided into two equal–area regions by an articulated central border and instructed them to report which side appeared closer. Observers chose the EE side on 100% of trials when EE and familiar configuration were present on the same side of the border (Congruent displays) and on 96% of trials when EE and familiar configuration were present on opposite sides (Incongruent displays; the difference of 4% was not statistically significant, p=0.20).Thus, observers overwhelmingly reported that the EE side was closer than the abutting side. We investigated whether the EE side is chosen as often when the task is to report which side of a border appears to be shaped. EE reports were significantly reduced when observers were instructed to report which was the shaped side of a border rather than which was the closer side. Observers reported that the EE side was the shaped side on 94% and 81% of trials with upright Congruent and Incongruent displays, respectively (p=0.029). In addition, the difference between EE-side reports on Congruent and Incongruent trials was larger for the shape task than for the relative distance task, at least when an upright familiar configuration was present on the opposite side of the border of incongruent displays rather than an inverted or a part-rearranged version of a familiar configuration, p <.05. Thus, the figural attributes of shape and near surface can be decoupled. Moreover, different figural cues differentially affect perceived shape and perceived near surface. EE exerts a relatively stronger influence than familiar configuration on the perceived-nearness than the perceived-shape.

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26.332 **Context Effects on Figure-Ground Perception with Both Convexity and Extremal Edge Cues** Katharina Mura[1,2](mura@rhrk.uni-kl.de), Tandra Ghose[1,2], Mary A. Peterson[3]; [1]University of Kaiserslautern, Germany, [2]German Institute of Artificial Intelligence (DFKI-Kaiserslautern), Germany, [3]University of Arizona, Tucson, USA

Convexity context effects (CCEs) have been demonstrated in figure-ground perception, where the figural bias of convexity increases from 57%-89% as the number of alternating convex and concave regions increases from 2 to 8 in 100-ms displays (Peterson & Salvagio, 2008). In 2-Region displays Ghose and Palmer (2010) found that when convexity conflicted with Extremal Edges (EE), the EE-side was perceived as closer on ~98% of trials (2000-ms exposures). We examined whether CCEs are obtained when convexity and EE cooperate (Congruent condition) or conflict (Incongruent condition). Observers reported whether a red probe located on the region to the left or right of a central border appeared to lie on the region they perceived as figure or ground; they were instructed that figures were both shaped and closer near the border. Convex regions were perceived as figures more often in 8-Region (92%) than 2-Region (77%) Congruent displays, p<.0001. Thus, EE benefits from context when combined with convexity. In contrast, convex regions were not perceived as figures more often in 8-Region (45%) than 2-Region (37%) Incongruent displays (p=0.089). Thus, when EE and convexity conflict, neither benefits from context. EE regions were perceived as figures on the majority of trials with Incongruent 2-Region displays (70%), replicating Ghose and Palmer, yet our observers perceived EE regions as figures less often than their observers perceived them as closer. Task or exposure duration differences may contribute to this result. A novel factor that affected 2-Region displays only also contributes: EE regions were less likely to be perceived as figure when they lay on the right (56%) versus left (84%) of the central border (p<.0001). We attribute this new finding to an influence on EE from a light-from-left bias that was overcome by context in 8-Region displays. Figure assignment is a complex interaction among a variety of cues.

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26.333 **Neural Signals Underlying the Convexity Context Effect** Jordan Lass[1](jwlass@gmail.com), Ali Hashemi[1], Patrick Bennett[1], Mary Peterson[2], Allison Sekuler[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University, [2]Department of Psychology and Cognitive Science Program, University of Arizona

Convexity is relevant to figure assignment, but the relationship is display-dependent: Convex regions are more likely to be perceived as figures in 8- than 2-region displays, provided concave regions are homogeneously colored. This convexity context effect (CCE) may occur because multiple homogeneous concave regions (8-region displays) are more likely than the single concave region (2-region displays) to be interpolated into a surface behind the convex regions, making convex regions stand out as figures in 3D. Without such interpolation, 2-region displays may appear flat. Here we examined the neural signals underlying CCEs using electroencephalography to determine the effect of region number and perceptual interpretation on those signals. On each trial, a small probe appeared on one of two central regions of 2- or 8-region black & white displays. Observers (N=10) indicated whether the region containing the probe was figure or ground. Overall behavioural results were in the direction predicted by the CCE, although there was considerable variability across individuals. Our most consistent result was an effect of region number on the P2 amplitude for the grand average evoked response potentials (ERPs), with greater amplitudes for 8- than 2-region displays (p<0.0001). We found additional, but smaller, effects of region number on P1 and N1 latency: 8-region displays led to earlier peaks than 2-region. At the group level, there were no effects of figure-ground perception up to about 300 ms. Highly variable behavioural CCEs obtained across subjects led us to examine effects of perceptual differences on ERPs. When considering just subjects with strong behavioural CCEs, P1 and N1 components showed an effect of perceptual interpreta-

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tion in the 8- but not 2-region displays. Overall, our results suggest that the magnitude of CCEs may be correlated with differences in early neural signals, and that the P2 may be linked to the perception of 3-dimensionality.

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26.334 **Can infants (5.5 months-old) use object repetition to segment objects from their backgrounds?** Elizabeth Salvagio[1,2](bsalvag@email.arizona.edu), Rebecca L. Gomez[1,2], Mary A. Peterson[1,2]; [1]Psychology Department, College of Science, University of Arizona, [2]Cognitive Science Program, University of Arizona

Brady and Kersten (2003) showed that some adults could learn to recognize a novel object paired with a sound, at least when instructed to look for it, when it was shown repeatedly against varying static backgrounds (texture and shading of object and background were identical). Can infants segment a novel object paired with a sound when it is shown repeatedly on static backgrounds? If so, must the backgrounds vary and/or differ in texture and shading from the novel object? We measured infants' preferences for two novel 3D objects during a pre-test and then showed them one of the novel objects repeatedly against varying backgrounds. During familiarization the object was accompanied by a labeling phrase. At post-test, infants viewed the familiarization object and the other object on a white background while hearing the familiarization object's phrase. If infants segmented the object from the background during familiarization, their post-test looking times at the familiarization object should be longer then at pre-test. In Experiment 1, we showed a 3D object on varying 2D background patterns. Infants looked longer at the familiarization object, but not the other object, post-test minus pre-test, $p < 0.006$, indicating they had segmented the object from the background during familiarization. In Experiment 2, we showed the same 3D object on 3D versions of the backgrounds with identical texture and shading as the object; the background differed on every trial. Evidence of segmentation was not observed at post-test, $p > 0.44$. In Experiment 3, we showed the same 3D object on a constant 3D background. Again, no evidence of segmentation was observed at post-test, $p > 0.36$. 5.5 month-old infants can segment without explicit instruction, at least when the background varies and differs in texture and shading from the object. An in-progress experiment attempts to separate these two factors.

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26.335 **Closure and global shape contributions to contour grouping** Ingo Fründ[1](mail@ingofruend.net), James H Elder[1]; [1]Center for Vision Research, York University, Toronto, ON, Canada

Perceptual organization of natural scenes is effortless and immediate despite fragmentation and obscuration of object boundaries caused by occlusions and clutter. The standard model for boundary grouping is based upon an 'association field' that governs local grouping, and a Markov or transitivity assumption that allows global contours to be inferred solely from local properties. Psychophysical 'path detection' experiments have revealed sensitivity to local geometry consistent with this association field hypothesis. Recently, however, it has been shown that detection of natural animal shapes is more efficient than detection of 'metamer' contours that match the natural contours in their local geometry but contain no global regularities (Elder et al, 2010, J Vis, 10(7):1171). This suggests that global shape also plays a role in contour grouping. Yet, since these metamer controls are open contours, the findings may derive purely from the closure of the natural shapes. To address this issue, we employ a novel MCMC methodology (Fründ & Elder, 2013, J Vis, 13(9):119) to produce closed metamer contours, statistically matched in their local geometry to natural animal shapes, but otherwise maximum entropy, containing no global regularities beyond closure. We conducted path detection experiments using these 3 stimuli (open metamers, closed metamers, natural shapes) at different contour sampling rates (number of elements per contour), and estimated noise threshold for criterion performance. At low sampling rates, performance was similar for the three conditions. However, as sampling rate was increased to 20 elements per contour, performance for natural shapes and closed metamers exceeded performance for open metamers ($t(7)>2.4$, $p<0.04$), and at 40 elements, performance for natural shapes exceeded performance for closed metamers ($t(10)=2.6$, $p=0.02$). These results show that the visual system exploits both closure and additional global properties of natural shape in the segmentation of bounding contours from cluttered scenes, challenging purely local accounts of contour grouping.

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26.336 **Invariants of center-surround interactions** Sunwoo Kwon[1](kwsunwoo@salk.edu), Thomas Albright[1], Sergei Gepshtein[1]; [1]Salk Institute for Biological Studies

Sensitivity to visual stimuli depends on their spatial and temporal context. Effects of temporal context (as in motion adaptation) that appear to be contradictory in narrow samples of stimuli follow a simple invariant pattern when viewed broadly. Thus, local gains and losses of sensitivity caused by motion adaptation added up to a global shift of the spatiotemporal contrast sensitivity function (CSF; Kelly, 1979) when studied over the full domain of CSF (Gepshtein, Lesmes & Albright, 2013). Similarly contradictory results are commonly observed in studies of spatial contextual modulation ("center-surround interactions") in narrow samples of stimuli. We asked whether a simpler pattern of sensitivity changes can be discovered in center-surround interactions when they are studied broadly, across the domain of CSF. We measured contrast sensitivity using direction discrimination in drifting Gabor patches with or without surrounding gratings. Center stimuli were sampled from a constant-speed "slice" of CSF (i.e., at constant ratio of temporal to spatial frequencies). When the surround was present, its spatiotemporal frequency and contrast were fixed within an experiment, its orientations was either collinear or orthogonal to the center, and its motion direction was either same or opposite to the center. The results varied across observers when center and surround moved in the same direction, possibly due to individual effects of motion capture. But the results were invariant across observers for all other conditions. What looked like a different pattern of gains and losses of sensitivity for every observer in narrow samples of stimuli, could be succinctly described as shifts of CSF following the same pattern across observers. At low surround contrasts, increasing surround frequency shifted the peak of CSF towards higher center frequencies. And at high surround contrasts, increasing surround frequency shifted the peak of CSF towards lower center frequencies.

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26.337 **Mechanisms of motion-based object segregation** Woon Ju Park[1,2](wjpark@bcs.rochester.edu), Duje Tadin[1,2,3]; [1]Center for Visual Science, University of Rochester, [2]Department of Brain and Cognitive Sciences, University of Rochester, [3]Department of Opthalmology, University of Rochester

Segregating objects from backgrounds is one of vision's most important tasks. A long-standing hypothesis links motion-based object segregation with suppressive center-surround mechanism. This proposed functional link has theoretical and neurophysiological support, but little direct behavioral evidence exists. Here, we investigated the role of background motion suppression in rapid object segregation. We hypothesized that perceptual insensitivity to large, background-like moving stimuli (Tadin et al., 2003) has a functional consequence of enhancing the relative visibility of moving objects on moving backgrounds. METHODS: At both low and high contrast, we measured subjects' ability to (1) detect moving stimuli (6°/s) across different sizes (1.5°-16° diameter) and (2) segregate a small moving object (1° diameter) presented on different sized moving backgrounds (also 1.5°-16°). Given our aim to study rapid motion segregation, we measured duration thresholds using a custom-built 360Hz display system. RESULTS: Size and contrast influenced both motion detection and segregation. Importantly, the relationship between the two tasks was negative. At high contrast, duration thresholds for motion detection gradually increased from ~6 ms for 1.5° stimuli to over 12 ms for 16° stimuli. Over the same range of background sizes, thresholds for motion segregation decreased from 12 to 5.5 ms. Remarkably, subjects were considerably better at detecting a moving object on a moving 16° background than detecting whether the same background stimulus was moving or stationary. At low contrast, we found pronounced spatial summation in the motion detection task (thresholds improved with increasing size). As predicted, the segregation performance was poor, and, unlike at high contrast, considerably worse than motion detection. CONCLUSION: These findings link spatial suppression with rapid motion segregation. Spatial suppression effectively accomplishes background subtraction and, as a result, increases visual saliency of object motion. This is a computationally and metabolically efficient strategy because object segregation is accomplished by suppressing irrelevant background information.

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26.338 **Perceptual Characteristics of Natural Contours and Their Contributions to Figure/Ground Segregation** Ko Sakai[1](sakai@cs.tsukuba.ac.jp), Ken Kurematsu[1], Shohei Matsuoka[1]; [1]Dept. Computer Science, University of Tsukuba

A piece of local, natural contour may evoke the perception of figure. We investigated what characteristics of natural contours provide the perception of figure. First, to examine what geometric factors could be the characteristics in the perception of contour, we performed similarity judgment among local, natural contours. Specifically, we tested whether geometric factors, such as convexity, closure and symmetry, explain perceptual similarity among the contours. We defined geometrically the three factors: for instance, convexity is defined as the logarithm of the curvature of the inscribed circle that passes through a point of a contour. We collected 50 patches from nearly 10,000 of local patches trimmed from natural images (the Berkeley Segmentation Dataset) so as to establish the equal distribution of the three factors. We performed psychophysical experiments to measure the similarity among the patches. MDS analysis showed the agreement between the arrangement of perceptual similarity and that of geometric factors, indicating that convexity, closure and symmetry are the characteristics used in the perception of contour. Second, we examined psychophysically whether convexity, closure and symmetry provide a clue in the perception of the direction of figure (DOF). A number of studies have reported the contribution of each factor to figure/ground segregation. In the present study, we focus on the combination of these factors, as they usually coexist in natural contours. We performed psychophysical experiments to judge the DOF at points along contours, and analyzed the dependence of the perception on the three factors. MLRA indicated that DOF is biased toward closure in comparison with convexity and symmetry. The result suggests that closure is dominant in the perception of DOF among mixtures of convexity, closure and symmetry as in natural contours.

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Motion Perception: Depth, higher order, illusions

Saturday, May 17, 2:45 - 6:45 pm
Poster Session, Banyan Breezeway

26.401 What do human observers see in dynamic image deformation?

Takahiro Kawabe[1](kawabe.takahiro@lab.ntt.co.jp), Kazushi Maruya[1], Shin'ya Nishida[1]; [1]NTT Communication Science Laboratories, Nippon Telegraph and Telephone Corporation, Japan

Image information of an object often deforms for various reasons. For example, a non-rigid object such as a rubber ball or a fabric can deform due to an external force and, as a consequence, produce an image deformation. On the other hand, image deformation can occur without the physical deformation of objects themselves. For example, an under-liquid scene is distorted due to refraction at the surface of the flowing liquid. In this case, a refractive transparent material intervening between the object and an observer causes image deformation of the underlying object. How does the visual system discriminate image deformation due to physical object deformation from image deformation due to the intervention of a transparent layer? The present study examined what human observers see during dynamic image deformation. We sinusoidally deformed the central area of two-dimensional 1/f noise. The spatial and drift frequencies of deformation were manipulated. Observers were asked to report the appearance of the deformed central area using three alternatives ('global object deformation', 'drifting grating', and 'transparent layer'), which were derived from a preliminary observation. Object deformation was often reported when the spatial frequency of deformation was low. Meanwhile, a transparent layer was predominantly reported as the spatiotemporal frequencies of deformation increased (i.e., dynamic transparency). Importantly, however, dynamic transparency was not observed when one-dimensional noise was employed as a background. In one-dimensional noise, image deformation occurred along an edge with consistent luminance polarity, and consequently enhanced perception of a global shape deformation. The visual system likely utilizes spatiotemporal frequencies of deformation and global shape as diagnostic features to discriminate image deformation due to physical object deformation from image deformation due to the intervention of a transparent material.

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26.402 Perception at isoluminance: Role of spatial resolution and background colour.

Mark Edwards[1](mark.edwards@anu.edu.au), Kimbra Ransley[1], Jason Bell[1,2], Stephanie Goodhew[1]; [1]Research School of Psychology, ANU, Australia, [2]School of Psychology, UWA, Australia

Introduction. The isoluminance paradigm, in which chromatically defined stimuli are matched for luminance, was developed to investigate the role of colour information in various aspects of visual processing. Performance is typically impaired, leading to the conclusion that particular tasks, e.g. motion and stereo processing, are substantially colour blind. However, other techniques that do not use isoluminance have shown that these processes are strongly sensitive to colour. One such technique is the chromatic noise-in-luminance approach: stimuli are defined by both colour and luminance, but the stimuli to be matched have opposite luminance polarities, e.g. a chromatic dot changes its luminance polarity as is moves. This leads to the question: why are some visual tasks impaired when isoluminant stimuli are used, even though the system is sensitive to colour information? Here we tested two possibilities: 1) colour sensitive cells have poor spatial resolution, and hence are impaired when fine spatial-resolution is required; 2) impairment is specific to isoluminant stimuli presented on a red background (Breitmeyer & Williams, 1990 Vis Res). Methods. Motion and form processing were assessed using global-dot-motion and Glass patterns, respectively. A temporal 2AFC procedure was used. Dot/dipole densities varied from 1 to 2 dots/deg2. The background was either achromatic (grey) or chromatic (red or green). Results. When the grey background was used, performance for the isoluminant dots was not impaired by increasing dot density. Thresholds being at least equal to the chromatic noise-in-luminance condition. Use of a red background impaired performance, particularly with the motion stimuli. Conclusions. Increasing dot density does not impair the processing of all isoluminant stimuli. However, when the stimuli and the background are both chromatic (red and green) performance is impaired, especially with motion stimuli on a red background.

Acknowledgement: Australian Research Council Discovery Grant DP110104553

26.403 A paradox: Apparent onset locations for moving stimuli are more extrapolated following illusory reductions in speed.

Paul Miller[1](paul.miller@uqconnect.edu.au), Derek Arnold[1]; [1]Perception Lab, School of Psychology, The University of Queensland

Humans make reliable errors when judging the instantaneous position of moving objects. In the Fröhlich effect, for example, the apparent onset location of a moving object seems advanced along its trajectory relative to static objects. We have found that this effect is malleable - exaggerated for tests following adaptation to motion in the same direction. We used arrays of rotating discs as an adaptor, and a single rotating disc in combination with static markers as a test. Neither opposite directional adaptation nor adaptation to slower movement had any impact. These data are counter-intuitive, as adaptation to fast motion reduced apparent test speeds, but exaggerated illusory displacements. Our data are consistent with apparent onset location being given by weighted positional estimates derived from multiple mechanisms with different integration times. We suggest that these estimates are re-weighted following adaptation to motion, increasing the relative contribution of mechanisms with more protracted integration times. This could be functionally adaptive, enhancing velocity judgments via increased temporal smoothing in dynamic conditions.

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26.404 Competing motion signals compromise to discrete perception

Ryohei Nakayama[1](nryohei@l.u-tokyo.ac.jp), Isamu Motoyoshi[2], Takao Sato[1]; [1]Department of Psychology, Tokyo University, [2]Department of Life Sciences, Tokyo University

In natural scenes, motion of an object as a whole is usually consistent with motion of local patterns contained within the object. We investigated human visual motion perception in cases where these motions conflict with each other, by using a Gabor pattern whose Gaussian spatial window and carrier grating moved inconsistently with different directions and/or speeds. We found that when spatial window moved constantly whereas the carrier grating stayed still or drifted in the opposite direction, the whole stimulus appeared to move only intermittently. This intermittent jumping motion was most strongly observed when carrier temporal frequency (relative to the window) was 4-8 Hz, and spatial frequency was 0.5-1 c/deg. The similar data was obtained even when the observer tracked the moving spatial window, indicating that the illusion is fundamentally determined at the spatiotopic coordinate. The apparent temporal rate of the jumping increased proportionally with the temporal frequency of the grating for a range from 4 to 10 Hz. Thus, the illusion is not determined by a fixed internal clock. The illusion diminished when the spatial window was surrounded by a sharp luminance edge. This jumping motion probably comes from resetting the positional representation of Gaussian window that occurs only intermittently. The visual system tolerates the discrepancy between the positional information of carrier grating determined clearly by luminance and that of Gaussian window determined only vaguely by a second-order motion (contrast defined) edge, and when the accumulated discrepancy becomes beyond certain limit, the positional representation of window is reset.

26.405 **Jumping Frogs: Prior Knowledge Influences the Ternus Effect** Patty Hsu[1](patty.hsu@mail.utoronto.ca), Wil Cunningham[1], Jay Pratt[1]; [1]Department of Psychology, University of Toronto

The Ternus effect is a robust bistable illusion of motion that produces element motion at short interstimulus intervals (ISIs; <50ms) and group motion at longer ISIs (> 50ms). Previous research has shown that the nature of the stimuli (e.g., similarity, grouping), not just ISI, can influence the likelihood of perceiving element or group motion. In the present study we examined if prior knowledge is also capable of influencing what illusory motion is perceived. To do so, our first experiment used a modified Ternus display with pictures of frogs in a jump ready pose that were facing forwards or backwards to the direction of illusory motion. The forward facing frogs afforded jumping over one another, which should promote element motion, while the backwards facing frogs should promote group motion. This was indeed found, as across ISIs ranging from 0 to 108 ms, participants perceived more element motion with the forward facing frogs and more group motion with the backward facing frogs. Our second experiment replicated the methods of the first experiment except that the frogs were shown in a sedentary "non-jumping" pose. As expected, we did not find a difference between forward facing and backward facing sedentary frogs. Presumably, the forward facing frog in this case did not produce more element motion because the sedentary pose did not afford a jumping motion. Thus, these two experiments provide more evidence that the Ternus effect cannot simply be attributed to the delay between the first and second display or to the physical characteristics of the stimuli. Rather, prior knowledge of the movement of certain animate objects, in this case frogs, also can modulate the perception of element or group motion.

26.406 **Revisiting the on-time effect: shorter exposure to static stimuli increases perceived velocity in apparent motion** Alon Zivony[1](alonzivony@gmail.com), Dominique Lamy[1]; [1]School of Psychological Sciences, Tel Aviv University, Tel Aviv

In apparent motion, static stimuli presented successively in shifted locations produce a subjective percept of continuous motion. It has been shown that reducing stimulus exposure (or on-time) increases the perceived velocity of the apparent motion. Surprisingly, little investigation has followed up on the illusion's discovery. The objective of this study was to delineate the boundary conditions of the on-time effect in order to clarify its underlying mechanism. Subjects viewed multi-item apparent motion displays. At a random point during the trial, on-time duration either increased or decreased, while objective velocity remained unchanged. Subjects were asked to judge whether the motion became slower or faster. The on-time effect was replicated in four experiments: it was observed in both fast and slow apparent motion displays; it was not modulated by stimulus luminance, thus precluding an energy-summation account of the illusion; it generalized to a time-perception paradigm; finally, it was found to be specific to apparent motion: with veridical motion, the effect reversed. We suggest that perceived velocity in motion is derived from a weighted average of exposure times to objective motion signals and to static motion signals.

26.407 **Rotating Snakes Illusion – Quantitative analysis reveals islands in luminance space with opposite illusory rotation** Michael Bach[1](michael.bach@uni-freiburg.de), Lea Gérard[1]; [1]Section Visual Function, Eye Center, Freiburg University, Germany

The "Rotating Snakes" illusion is based on patterns with repeated asymmetric luminance steps, arranged in concentric bands forming a "snake wheel". In the underlying luminance sequence "black – darker grey (g1) – white – lighter grey (g2)" we varied the luminances of g1 and g2, and measured illusion strength via a nulling task: On a gamma-corrected VDU, repetitive saccades were performed passing a "snake wheel" that physically rotated, and the participants adjusted rotation direction and speed until a stationary percept obtained. We found that our participants performed perceptual nulling (in the range of ± 1°/s) of the seeming rotation quite reliably and convincingly; when the gaze was directed to the center of the wheel after null-adjustment, the actual rotation could be quite surprising (depending on the levels [g1, g2]). Typical settings for [g1, g2] as measured from images by A. Kitaoka, are around [20%, 60%]. Indeed, we found a marked illusion in an "island" region [g1≈{0–25%}, g2≈{20–75%}]. Unexpectedly, we detected a second island around [60%, 90%] with opposite rotation direction, although the relative order of g1 and g2 stayed the same. Furthermore, there was also some rotation illusion when altogether only 3 luminance levels were visible, e.g.: 0–0–50–100%. These quantitative measurements of illusion strength have revealed new phenomena in this illusion, which challenge the two explanatory models put forth so far.

26.408 **Perception of Illusory Motion in the Rotating Snake by the Aged: Pupil Size and Retinal Illumination** Patricia Cisarik[1](pcisarik@sco.edu), Gabriel Fickett[1]; [1]Southern College of Optometry

Decline of visual functions occurs with aging.1 Perceived motion in repeated asymmetric stationary patterns, such as Kitaoka's Rotating Snakes, is no exception: Billino, et al. reported that only 23.7% of their 38 subjects 65+ years of age perceived the illusory motion, compared to 100% perception by young adults.2 Neurophysiology data provides evidence that timing differences in V1 cell responses to luminance contrast variations account for the illusion;3 therefore, degeneration of visual cortex with age4 has been suggested to cause degraded perception of this illusory motion.2 Since senescent optics of the eye insufficiently explain the decline of several visual functions,6,7 the contribution of pre-cortical factors to the age-related decline in illusory motion perception is presumed to be minimal and has not been investigated.Because reduced retinal illumination degrades the perception in young subjects,5 we initiated a pilot study in individuals aged 60+ years to qualitatively investigate the effects of retinal illumination on illusory motion perception in the elderly. Inconsistent with Billino, et al., 80% of our subjects perceived motion in the Rotating Snakes, possibly due to the younger mean age of our group (69.6 vs. 73 years). A t-test for independent samples indicates that the mean age of those who perceived the illusion is younger (67.8 vs. 76.2 years, $p = .01$) and the mean pupil size is larger (3.8mm vs. 2.4mm, $p = .002$) than the mean age and pupil size of those who did not perceive the illusion. In the subset of pseudophakic subjects, no difference was found in the mean age of those who did compared to those who did not perceive the illusion ($p = 0.2$); however, those who perceived the illusion had a larger pupil than those who did not (4.7mm vs. 2.3mm, $p = 0.03$). Our results suggest that reduced retinal illumination contributes to the declined perception of illusory motion in repeated asymmetric stationary patterns with aging.

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26.409 **Illusory rotation and motion capture in Pinna illusion depend upon grouping of the superimposed elements.** Makoto Ichikawa[1](ichikawa@L.chiba-u.ac.jp), Yuko Masakura[2]; [1]Department of Psychology, Chiba University, [2]School of Computer Science, Tokyo University of Technology

When viewing the concentric circles, which consist of oblique components, the observers see an illusory rotation of the circles by changing the viewing distance (Pinna & Brelstaff, 2000, Vision Research, 40, 2091-2096). If several additional elements were superimposed on the concentric circles, they will see the illusory rotation not only for the circles, but also for the superimposed elements (Ichikawa et al, 2006, Perception, 35, 933-946). This illusory rotation of the superimposed elements, which have no means for generating illusory motion themselves, is based on "motion capture". In this study, we examined how the grouping of superimposed elements affect the illusory rotation for the circles (136mm in diameter) and motion capture for the superimposed elements that were located at the inner area of the concentric circles. The inner and outer rings each consist of black or white 72 oblique lines on a gray background. Each line was tilted radially by 30 degree. The sum of black and white dots was 40. Within those 40 dots, the amount of black dots was 0, 4, 10, 20, 30, 36, or 40. Observers viewed the stimuli by repeatedly moving the head forward and backward at a rate that felt comfortable. They reported the direction of the rotation, and evaluated the magnitude of the illusory motion for the inner and outer circles, as well as the superimposed dots. The illusory rotation for the inner circle and motion capture most reduced when the amount of black dots was 20, and grouping of dots was difficult because no proximal dots organize a group in terms of similarity in luminance. These results suggest that the motion capture for the superimposed elements is caused by the leakage of motion signal from the oblique components, and accumulation of that motion signal within each group of superimposed elements.

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26.410 **The effect of noise on motion binding is similar in younger and older adults** Jessica N. Cali[1](calij@mcmaster.ca), Patrick J. Bennett[1], Allison B. Sekular[1]; [1]Psychology Neuroscience and Behaviour, McMaster University

The level of internal noise affecting motion processing is higher in older than younger adults (Bennett et al., Vision Res, 2007; Bocheva et al., Exp Brain Res, 2013). Normally, higher noise is associated with poorer performance; however, Lorenceau(Vision Res, 1996) showed that visual stimulus noise sometimes can help perception. In Lorenceau's task, a square stimulus composed of dots (5/side) maintained a fixed orientation while rotating around central fixation. The square's rotation was decomposed into

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two sinusoidal components corresponding to the motion of the horizontal and vertical lines. Critically, the corners of the square were removed, so participants had to combine the two motion components to discriminate the global rotation (clockwise or counter-clockwise). Lorenceau found that motion binding was easier when noise was added to the individual dots forming the square. Here we asked whether age-related changes in internal noise would affect perception, with seniors potentially requiring less external noise to perceive the global motion. We tested younger (19-27 years; N=6) and older (64-75 years; N=6) adults using Lorenceau's stimulus displayed for 4 durations (150ms, 300ms, 600ms, 1200ms) at 3 levels of external noise (0.0002, 0.027, 0.081). In general, we found a similar pattern of results as Lorenceau, with better performance at higher levels of noise, but the effect of the noise depended on stimulus duration. At 150ms, there was no difference across noise levels for younger or older adults. As trial durations increased, performance increased in the moderate and high noise conditions, and decreased in the low noise condition. A similar overall pattern was observed for both age groups, although maximum performance differed numerically, but not significantly, for older (~85%) versus younger (~95%) observers. Additional studies are examining whether clearer age-related effects are seen at more extreme noise levels, and whether seniors might benefit from even longer stimulus durations.

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26.411 **Walking with Cornsweet: Polarity Reversals Induce Illusory Motion Percepts** Christopher Blair[1](netiger@hotmail.com), Lars Strother[1], Gideon Caplovitz[1]; [1]Psychology, University of Nevada, Reno

Here we present an original illusion in which polarity reversing, stationary Craik-O'Brien-Cornsweet stimuli viewed under maintained fixation appear to move with dramatic unpredictable trajectories. Some stimulus configurations can lead to significant distortions of shape. For example, in addition to appearing to wander across the screen, a polarity reversing circle may appear to continuously deform such that it appears like an oval or even a polygon. Both the distortions and global motion largely arise from the distribution of local motion signals that are generated along the polarity-reversing contour. For example, a polarity reversing Cornsweet line may appear to move in either of the directions orthogonal to its contour and does not appear to deform. Whereas a pattern reversing circle, which has local motion pointing in all directions, may appear to wander aimlessly across the screen and deform in any number of ways. These effects appear to be strongest when stimuli are viewed peripherally, and polarity reversals occur at a rate 8-12 Hz. These effects are greatly reduced for non-Cornsweet stimuli, such as a light and dark line side by side, or a unipolar Gaussian contour.

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26.412 **Temporal Context Effect is not Specific to Brightness** Joshua Erb[1](jde2131@columbia.edu), Chris Davies[1], Jorge Morales[2], Hakwan Lau[1,3]; [1]Psychology, Columbia University, [2]Philosophy, Columbia University, [3]Psychology, University of California Los Angeles

Many aspects of visual perception are affected by spatial context. However, D. Eagleman has demonstrated that brightness, the perception of an object's luminance, is also affected by temporal context (1). This temporal context effect (TCE) is organized such that in a two stimulus brightness comparison task, the short stimulus is perceived as brighter than an isoluminant longer stimulus if offset-matched to the longer stimulus, and dimmer if onset-matched. Eagleman's original model for how the TCE is achieved is similar in spirit to the anchoring rule in brightness perception reported by A. Gilchrist (2). However, one can imagine that other mechanisms based on neuronal adaptation or normalization may also account for these findings, but would predict that the TCE may generalize to other stimulus features such as contrast and motion coherence. We examined whether the TCE extends to the perception of motion coherence using motion dot stimuli. Though we observed an effect less robust than the original TCE for brightness, the proportion of trials in which the short stimulus was perceived as more coherent than the long stimulus was greater in the offset-matched condition than in the onset-matched one. To a somewhat lesser extent, the effect also generalized to perceived contrast for gratings. Since one difference between our experiments and the original TCE brightness study was our use of untrained psychophysics subjects, we replicated the brightness TCE with untrained subjects and also showed compromised robustness, suggesting that our observed effects are not necessarily weaker than the brightness TCE. These results call for a mechanism for the TCE that is not specific to brightness perception, and motivates neuroimaging experiments to investigate a general neural mechanism (which are in progress). References: 1 -Eagleman D.M., Jacobson J.E., Sejnowski T.J. (2010). Nature, 428(6985), 854-856. 2 -Gilchrist, A., et al (1999). Psychological Review, 106(4), 795-834.

26.413 **Can Preferential Looking be Used to Assess Depth Perception in Infants Who Are too Young to Reach?** Vanessa Adamson[1](adams944@umn.edu), Tobias Donlon[1], Sherryse Corrow[2], Albert Yonas[1]; [1]University of Minnesota-Twin Cities , [2]University of British Columbia

It has been established that 7-month-old infants perceive 3-D layout from motion-carried, binocular, and static-monocular depth cues, by using preferential reaching. In these studies, infants reached to the apparently closer part of the display. Reaching preference was compared under monocular and binocular viewing conditions. Perception of depth from pictorial cues was less consistent in younger infants. A different response is required to gauge depth perception in infants who are too immature to reach with precision. There is some evidence that infants prefer to fixate the apparently closer of two objects. The goal of the first study was to test the hypothesis that young infants prefer to fixate the apparently closer portion of a display. STUDY 1: Four-month-old infants (n=28) were presented with boundary-flow (relative motion) information for depth. Infants viewed the display binocularly because it is known that adults perceive a strong depth effect when boundary-flow display is viewed binocularly. Eye fixation and duration were analyzed using an eye tracker. Results: We found no evidence that the apparently closer part of the display received more attention by 4-month-old infants. STUDY 2: Four to 5-month-old infants (n=8) were presented with a highly effective combination of two pictorial depth cues, familiar size and relative size, and a trapezoidal window display viewed with one or two eyes. Motion of the displays was presented to attract attention. Results: We found no evidence that the apparently closer part of the display received more attention monocularly than binocularly. CONCLUSIONS: Preferential looking may be an ineffective method for evaluating the development of sensitivity to depth information in infants too immature to reach. A tendency to look at closer objects may appear between 4 months or 5 months as infants begin to reach to objects within reach. We plan to test older infants to explore this possibility.

26.414 **Systematic biases in 3D motion perception as a function of sensory uncertainty** Jacqueline M. Fulvio[1](fulvio@wisc.edu), Monica L. Rosen[2], Bas Rokers[1,3]; [1]Department of Psychology, University of Wisconsin - Madison, [2]Department of Psychology, University of Central Florida, [3]Department of Psychology, Utrecht University, the Netherlands

Many stereotypical behaviors in contour extrapolation, cue integration, and motion perception can be understood as the result of optimal inference under sensory uncertainty. In 3D motion perception, observers' estimates of object motion are typically biased laterally: objects on a collision course with the head are judged as missing the head (Harris & Dean, 2003; Welchman et al., 2004). These biases have been modeled as the result of differential reliability in lateral motion and motion in depth estimation (Lages 2006; Welchman, 2008) combined with a prior expectation for slow speeds (Simoncelli, 1993; Weiss et al., 2002; Stocker & Simoncelli, 2006). A critical test of this explanation requires investigation of 3D motion estimation under variable levels of uncertainty. Here we aim to advance the understanding of the motion estimation biases through development of a framework that supports systematic manipulation of sensory uncertainty. On each trial, a target moved along a linear trajectory in the x-z plane for 1s before disappearing. The observer subsequently adjusted the position of a 'paddle' along a circular orbit, so that the paddle would have intercepted the target, providing an estimate of the observer's perceived motion direction. We manipulated noise in two ways. In the external noise manipulation, the target appeared at fixation with one of three contrast levels: 100%, 10%, 6.5%. In the internal noise manipulation, a 100% contrast target appeared in a location in front of, behind, or at the fixation plane. Estimated motion direction of 100% contrast targets at fixation was near veridical. However, significant lateral biases in trajectory estimates emerged with both noise manipulations. Analyses of the depth and lateral components of the estimates both reflected increased uncertainty due to noise. In conclusion, these results provide direct evidence that biases in visual processing arise under sensory uncertainty, be it from internal or external noise.

26.415 **Examining the role of eye movements in the size-speed illusion.** Helen E. Clark[1](hclark@waikato.ac.nz), John A. Perrone[1]; [1]University of Waikato, New Zealand

Large objects appear to move slower than small objects (Leibowitz, 1985). This size-speed illusion may account for collisions between motor vehicles and trains at level crossings. Recent research has shown that approaching computer generated trains appear to be moving more slowly than motorcars (Clark, Perrone, & Isler, 2013). What is currently not known is the underlying mechanism responsible for this illusion. One possible reason for the misperceived relative speed is that different patterns of eye movements occur for the different sized objects. The perspective image of an approaching train is quite different to that of a car, with the front significantly larger than the back. It has been shown that initial saccades made to two unequal-sized stimuli land between the stimuli, but tend to fall closer to the larger stimulus than the smaller stimulus (Findlay, 1982). The length of such objects also appears to dictate saccadic landing positions, with longer objects having a more 'off-centre' landing position (Vitu, 1991). We therefore tested observers' relative speed perception for two computer generated moving objects (short and long) moving obliquely in depth towards the eye and presented sequentially. Image (x,y) position and eye velocity were recorded as the observers judged the objects' relative speed. Saccadic behavior was different for the short and long objects; initial saccades were localised around the visual centroid ('center of gravity') of the objects and hence were further from the front of the larger, long objects than the smaller ones. Pursuit velocities were also different and were slower for the long object. When observers were forced to track a fixation point at the same frontal location on the short and long objects the size-speed illusion was eliminated. Therefore different fixation positions and pursuit speeds for the small and large approaching objects seem to account for the illusion.

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26.416 **Minimum Motion/Pursuit Ratios for Unambiguous Depth Perception from Motion Parallax**

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The unambiguous perception of depth from motion parallax (MP) relies on both retinal image motion (dθ) and extra-retinal pursuit eye movement (dα) signals, which are scaled with viewing distance (f). The motion/pursuit ratio (M/PR) describes how relative depth from motion parallax (dMP) can be quantified from these signals: $dMP / f = d\theta/d\alpha$. The purpose of the current study is to determine the lower limits of the M/PR parameter space in which observers can still accurately perform near/far relative depth-sign discriminations for a translating motion parallax stimulus. Stationary observers used pursuit to follow a translating random-dot MP stimulus window depicting a vertical sinusoid. Their psychophysical task was to indicate the perceived depth-phase of the sinusoid, which varied depending on the relative directions of the dθ and dα components. In separate conditions the MP stimulus window translated leftward or rightward at one of several velocities (dα: 1.3 - 25 d/s). Within conditions, peak stimulus dot velocity (dθ) varied in an interlaced staircase procedure (for different directions of stimulus window translation) down to a floor of 0.0067 d/s. The direction of stimulus dot movement, which determined stimulus depth phase, was randomized. For most observers, the minimum M/PR for the unambiguous perception of depth from motion parallax is found to be constant around 0.02, across a range of pursuit velocities. However, this changes for pursuit velocities less than ~7 d/s. Here, this minimum M/PR begins to increase as the pursuit velocity decreases. This likely reflects limits in retinal image motion processing (dθ), during pursuit eye movements. This pattern of results, especially the transition at ~ 7 d/s, is similar to previous parallactic depth thresholds documented by Ono and Ujike (2005) and Ujike and Ono (2001) when accounting for the possible differences in head-stationary and head-moving conditions.

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26.417 **Illusory perception of alternating vertical apparent motion in sequential random texture displays**

Jake Smith[1](jakesmeeth11@gmail.com), Yeram Cheong[1], John Rogers[1], Nicolas Davidenko[1]; [1]Psychology Department, UC Santa Cruz

We report a novel illusion in the perception of sequential random texture displays. In 3 experiments, participants consistently perceive alternating vertical apparent motion when random textures were shown sequentially. In Experiment 1, 18 participants viewed 6-frame sequences of 140x140 pixel square arrays presented at 2.5 Hz. The first frame was a random array of black and white pixels; the 5 subsequent frames were shifted by 4 pixels in some cardinal direction, with additional pixels added to the receding edges. Half of the displays showed alternating apparent motion (Up-Down-Up-Down-Up or Right-Left-Right-Left-Right) and half showed same-direction motion (Up-Up-Up-Up-Up or Right-Right-Right-Right-Right). Participants were asked to indicate if they detected apparent motion, and if so, which type. Across trials, varying amounts of noise were added to the frames, ranging from 0-noise (100% coherence) to 1-noise (0% coherence). Participants' performance at 0-noise was nearly perfect (95.5%) and dropped sharply as noise was added. Interestingly, strong biases emerged at noise levels above 0.5. Specifically, at 1-noise participants reported perceiving coherent motion on 41% of trials; of those, 56% were perceived as alternating vertical, and 25% as alternating horizontal, indicating statistically reliable alternating (p=0.002) and vertical (p=0.01) biases. In Experiments 2 and 3, we measured hysteresis by adding or subtracting noise dynamically. In Experiment 2, 27 participants saw sequences starting at 0-noise in which noise was incrementally added, and in Experiment 3, 35 participants saw sequences at 1-noise in which noise was incrementally removed, revealing one of the 4 types of underlying apparent motion. In both experiments, participants consistently perceived alternating vertical motion even at 1-noise. Together our data indicate 3 biases in the perception of sequential random texture displays: (1) perception of coherent apparent motion when there is none; (2) perception of alternating (over same-direction) motion; and (3) perception of vertical (over horizontal) motion.

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26.418 **Sensitivity to Newtonian mechanical regularities in causal perception: Evidence from attention**

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One of the most remarkable features of human perception is its ability to represent causation. Here we demonstrate that causal perception is sensitive to certain physical regularities in collision events that result from Newtonian mechanics. Consider two balls, A and B, with A moving towards B at 1 m/s and B at rest. When A is with B, A stops moving and B begins moving in the same direction. According to Newtonian mechanics of collisions, B cannot move faster than 2 m/s in this example, no matter the difference in masses between A and B. It is well established that if B moves at any speed less than 2 m/s, people will perceive this collision as a causal "launching" event (Michotte 1946/1963). When participants observe collision events that violate this principle, e.g. if B moves at 3 m/s, they still perceive a causal relationship, but report that the event seems unnatural. Building on these reports, the current project asks whether causal perception is sensitive to these regularities in Newtonian mechanics. We employ a novel visual search task in which participants are required to locate a single collision event with an unequal speed ratio between A and B (1:3 or 3:1) in the presence of two 1:1 launching events. We find that people are robustly faster at detecting collision events that violate these regularities (1:3 speed ratio) than collision events with the inverse speed ratio (3:1), which are seen as launching. However, there is no such difference in minimally different events that do not involve the perception of causality (e.g., events with a temporal or spatial gap) (Fig. 1). These results suggest that causal perception is sensitive to principles of Newtonian mechanics.

26.419 **Differentiating between object-dependent and transient-dependent motion percepts through crowding**

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Motion can be perceived by detecting changes in an object's location, or by detecting transient changes in sensory channels (e.g. luminance). The relative contribution of these mechanisms can be difficult to ascertain in many situations. We used spatial crowding to dissociate object- and transient-dependent mechanisms, reasoning that crowding should impair motion perception relying on object localization. Experiment1 investigated continuous motion, perception of which is typically thought to rely upon transient detection. A gray disc moved continuously through 0.64°, and participants reported the motion direction (left or right). Crowding of the moving disc by stationary discs more severely impaired judgment accuracy for slow (.08°/s) than fast (0.64°/s) motion. This result suggests that perception of slow continuous motion relies more on higher-level object systems, probably because slow motion produces transient signals that are too weak for summation. Experiment2 applied a crowding manipulation to the Ternus display, which is known to elicit percepts of element motion (one object moving with two stationary middle objects) or group motion (all three objects moving together). We hypothesized that element motion is possibly the output from transient detectors, since this percept violates object coherence. In contrast, group motion should be the output of an object-dependent system, as it arises from a construal of the least coincidental change to all objects. Participants viewed 0ms ISI displays, and reported whether they saw group or element motion. With stationary bars crowding the Ternus stimuli, participants reported predominantly element motion, whereas group motion was reported predominantly with uncrowded stimuli. These results suggest that Ternus percepts are the outputs of independent motion systems, differentially reliant upon low-level

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transients vs. object position representations. Together, these experiments evidence the utility of crowding to isolate motion systems, and suggest a taxonomy of motion perception deriving from its informational basis.

26.420 **Tilt-rate perception in vehicle simulation: the role of motion, vision and attention** Paolo Pretto[1](paolo.pretto@tuebingen.mpg.de), Alessandro Nesti[1], Suzanne Nooij[1], Martin Losert[1,2], Heinrich Bülthoff[1,3]; [1]Human Perception, Cognition and Action, Max Planck Institute for Biological Cybernetics, Tübingen, Germany, [2]Department of Psychology, University of Tübingen, Tübingen, Germany, [3]Department of Brain and Cognitive Engineering, Korea University, Seoul, Korea

In vehicle simulation (flight, driving) simulator tilt is used to reproduce sustained acceleration. In order to feel realistic, this tilt is performed at a rate below the tilt-rate detection threshold, which is usually measured in darkness, and assumed constant. However, it is known that many factors affect the threshold, like visual information, simulator motion in additional directions, or active vehicle control. Since all these factors come together in vehicle simulation, we aimed at investigating the effect of each of these factors on roll-rate detection threshold during simulated curve driving. The experiment was conducted on a motion-based driving simulator. Roll-rate detection thresholds were determined under four conditions: (i) roll only in darkness; (ii) combined roll/sway in darkness; (iii) combined roll/sway and visual information whilst passively moved through a curve; (iv) combined roll/sway and visual information whilst actively driving around a curve. For all conditions, motion was repeatedly provided and ten participants reported the detection of roll in a yes-no task. Thresholds were measured by adjusting roll-rate saturation value according to a single-interval adjustment matrix (SIAM) at every trial. Mean detection threshold for roll-rate increased from 0.7 deg/s with roll only (i) to 6.3 deg/s in active driving (iv) (mean threshold was 3.9 deg/s and 3.3 deg/s in conditions (ii) and (iii) respectively). However, large differences between participants were observed: for some the threshold did not increase from passive to active driving; while for others about 3 times higher threshold was measured, and lower level of attention was reported on questionnaires. We conclude that tilt-rate perception in vehicle simulation is affected by the combination of different simulator motions. Similarly, an active control task seems to increase detection threshold for tilt-rate, i.e. impair motion sensitivity. Results suggest that this is related to the level of attention during the task.

26.421 **Automatic selection during simultaneous motion processing** Reuben Rideaux[1](reuben.rideaux@anu.edu.au), Mark Edwards[1]; [1]Research School of Psychology, College of Medicine, Biology and Environment, The Australian National University

Introduction. When confronted with multiple moving objects the visual system can process them in two stages: an initial stage in which a limited number of signals are processed in parallel (i.e. simultaneously) followed by a sequential stage. We previously demonstrated that during the simultaneous stage, observers are capable of simultaneously extracting direction information, which is bound to its corresponding element, from up to 3 signals (Vis Res, In press). When the number of elements presented exceeds this capacity, a subset of up to 3 can be automatically selected and processed. Here we investigate which element characteristics influence bottom-up saliency, driving this automatic selection process. Method. This was achieved by briefly presenting observers with 8 localized motion signals, each consisting of a group of four dots arranged into a square formation, then post-cueing one of the signals and measuring the accuracy at which observers identified its direction during the presentation. By systematically varying characteristics of the elements presented and examining performance as a function of these, we determined patterns of selection based on the following features: spatial location, direction, speed, and contrast. Results. The results show that when presented with a heterogeneous population of motion signals exceeding the limit of simultaneous processing, observers consistently demonstrated significant selection bias based on these characteristics. Elements presented at greater eccentricity, moving in cardinal directions, moving relatively faster, and of higher contrast are more likely to be selected than their counterparts, i.e. low eccentricity, oblique directions, slower, and low contrast. Conclusions. This indicates that during simultaneous motion processing, the automatic selection of signals is driven by variations in bottom-up saliency resulting from relative differences in both motion-specific characteristics, i.e. direction and speed, and other characteristics, i.e. spatial location and contrast.

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26.422 **Facial feature changes are hard to track in the color wagon-wheel illusion** Arthur Shapiro[1](arthur.shapiro@american.edu), William Kistler[1]; [1]Department of Psychology and Center for Behavioral Neuroscience, American University

Introduction: The color wagon-wheel illusion (Shapiro, Kistler, & Rose-Henig, 2012) separates two opposing types of motion.For instance, consider a rotating ring composed of twelve disks separated from each other by 30 deg, with eleven of the disks black and one yellow. If the ring rotates clockwise at 25 deg/frame, then the black disks appear to rotate counter-clockwise at 5 frames/sec (a first-order motion process) while the yellow disk appears to rotate clockwise (a feature-tracking or third-order motion process). Here, we use variations of the color wagon-wheel illusion to examine the processes underlying our ability to track objects that differ from each other in terms of the structure of their internal features. Methods: The basic experiment presents a ring of twelve equally spaced faces: eleven identical faces and one that differs only in expression (same face for all twelve disks). The experiment manipulated the features of the single odd face and the speed of ring rotation. Observers responded as to whether they could track the motion of the odd face. Results When the ring rotated at 30 deg/frame, observers could easily track the motion of the odd face (>90 percent of trials) since the only observable motion was the odd face shifting position around the ring. When the ring rotated at speeds greater than or less than 30 deg/frame, the motion of the odd face had to compete with the aliased rotation of the ring. In such conditions, observers' ability to track the odd face was markedly degraded. However, observers were able to track successfully at all rotation speeds if a luminance signal was added to the odd face. Conclusion: Competing motion signals degrade an observers ability to track motion based purely on changes in facial features but not the ability to track motion that includes identifiable luminance information.

26.423 **1st and 2nd order stimuli reaction time measures are very sensitive to mild traumatic brain injuries.** Jean-Claude Piponnier[1](jean-claude.piponnier@umontreal.ca), Robert Forget[2], Isabelle Gagnon[3], Michelle Mckerral[4], Jean-François Giguère[5], Jocelyn Faubert[1]; [1]Visual Psychophysics and Perception Laboratory, École d'Optométrie, Université de Montréal, Montréal, Québec, Canada, [2]École de réadaptation, Université de Montréal, Montréal, Québec, Canada , [3]Montreal Children's Hospital, McGill University Health Center, Montreal, Quebec, Canada, [4] Centre de Recherche en Neuropsychologie et Cognition (CERNEC) and Department of Psychology, Université de Montréal, Montréal, Québec, Canada , [5]Department of Surgery, Sacré-Cœur Hospital affiliated with Université de Montréal, Montréal, Quebec, Canada

We investigated the impact of mild traumatic brain injury (mTBI) on visuomotor processing of first and second order contrast using flickering or motion defined sinusoidal gratings. Spatial frequency was 0.5 cpd and temporal frequency was 2 Hz. Flicker consisted in contrast inversion, and motion drifted right or left. Contrast was 12.5% for first and 100% for second order, difference usually observed in perception thresholds, and used to make measures of first and second order comparable. Reaction times (RTs) of 15 adults diagnosed mTBI were compared to those of 15 matched controls. Measurements were obtained at 15 days, 3 months and 12 months after the injury, and at equivalent times for control participants. Detection RTs, for the flicker condition, and direction discrimination RTs, for the motion condition, were measured. For RTs corresponding to correct responses, means, standard deviations (SDs), medians, interquartile ranges (IQRs) were calculated. In general, RTs of mTBI were longer than control subjects as revealed by means ($p=0.031$) and medians ($p=0.037$). For mTBI group motion condition, RTs corresponding to 1st order were shorter than those corresponding to 2nd order stimuli (means: $p=0.001$; medians: $p<0.0001$). SDs ($p=0.031$) and IQRs ($p=0.040$) were larger for mTBI than for control participants. Control group SDs were smaller for detection RTs than for direction discrimination RTs ($p=0.007$), but IQRs revealed this was true for both groups ($p <0.0001$). For the mTBI group motion condition, SDs ($p=0.047$) and IQRs ($p=0.013$) were larger for 1st than for 2nd order. All these observations were made over the 3 sessions. The use of RT measures, combined with stimulus properties, appear to be a very sensitive method for measuring mTBI-induced visuomotor anomalies. The different stimulus properties allow for fine probing of the underlying mechanisms in conditions where the brain is exposed to mild trauma.

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26.424 **Deterioration of visual motion perception in mesopic vision**

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We empirically know that visual motion perception deteriorates in mesopic vision, where both rods and cones operate. Visual motion priming is a phenomenon in which the perceived direction of a directionally ambiguous test stimulus is influenced by the moving direction of a preceding priming stimulus. To examine the integration of motion signals at mesopic light levels, where cones operate in the central retina and rods in the peripheral retina (Raphael & MacLeod, 2011), we presented the priming and test stimuli in the central and peripheral retinae, respectively. Subjects judged the perceived direction of the 180° phase-shifted sine-wave grating (rightward or leftward) that was followed by a smoothly drifting priming stimulus at different retinal illuminances (from −1.5 to 2.8 log Td). We found that the strength of motion priming was greatly decreased at mesopic, but not photopic and scotopic, light levels. When the test stimulus was presented before the offset of the priming stimulus, motion priming was prominent irrespective of the retinal illuminance. This finding indicates that the temporal delay in the rod pathway weakens the integration of motion signals in mesopic vision. In a separate experiment, subjects made a saccade after the termination of the priming stimulus and then performed the task involving judging the direction in retinotopic and spatiotopic coordinates (Burr & Morrone, 2012). In the spatiotopic condition, the priming and test stimuli occupied the same position on the display across a saccade. We found that motion priming in the spatiotopic condition was greatly decreased at mesopic, but not photopic and scotopic, light levels. These results suggest that incompleteness in the integration of motion signals due to insufficient build-up of the spatiotopic representation by the temporal delay in the rod pathway causes visual motion perception deterioration in mesopic vision.

Motion Perception: Neural mechanisms

Saturday, May 17, 2:45 - 6:45 pm

Poster Session, Banyan Breezeway

26.425 **The Responses of On-Off Directionally Selective Retinal Ganglion Cells to Sudden Motion-Onset**

Timothy Gawne[1](tgawne@gmail.com), Allan Dobbins[2], Franklin Amthor[3]; [1]UAB Dept. Vision Sciences, [2]UAB Dept. Biomedical Engineering, [3]UAB Dept. Psychology

Introduction On-Off Directionally-Selective Retinal Ganglion cells (DS RGCs) are robustly tuned for the direction of a moving visual stimulus, but it is still not clear what their role in perception is. One possibility could be in responding to the motion onsets caused by head movements, which are important in computing distance via motion parallax. Because On-Off DS RGCs exhibit hyperacuity-level discrimination for small movements (Grzywacz et al. 1994), these cells might be especially well suited for this task. Methods Pigmented rabbit retinas were prepared for single-unit recording in a superfused eyecup preparation. A video image was projected onto the retina. Visual stimuli were flashed in the center of the RF, allowed to stabilize for one second, then moved abruptly at different speeds and directions. Results Response latency decreased with increasing speeds, with relatively little effect of stimulus direction or luminance. On the other hand, the response magnitude (spike count) was a strong function of stimulus direction, with relatively less effect of stimulus speed or luminance. Using only the first 300 msec of a single response, a neural network predicted the stimulus speed (actual vs. predicted R=0.85). Again using only the first 300 msec and a single trial, a simulated quartet of cells with complementary directional tuning predicted the stimulus direction (actual vs. predicted R=0.89). Conclusion Stimulus speed is encoded via the high frequency content of the spike train, while stimulus direction is encoded in the low-frequency information, permitting straightforward decoding. The experiments and simulations demonstrate that an object's speed and direction can be obtained rapidly after movement onset by On-Off DS RGCs.

Acknowledgement: NSF grant IOS 0622318

26.426 **Effect of continuous theta burst stimulation (cTBS) of human brain areas MT+ and V1 on color and motion perception.**

Shaleeza Kaderali[1](shaleeza.kaderali@mail.mcgill.ca), Yeon Jin Kim[1], Alexandre Reynaud[1], Kathy T. Mullen[1]; [1]McGill Vision Research, Department of Ophthalmology, McGill University

Introduction: Previous studies on chromatic and luminance defined global motion have established a dissociation between visual thresholds for direction discrimination and stimulus detection (Michna & Mullen, JOV 8(5):10, 2008). Here we use cTBS (a repetitive TMS protocol) to investigate the differential effects of stimulation on these thresholds in areas hMT+ and V1. We use both luminance and isoluminant chromatic global motion stimuli. Methods: Brain areas hMT+ and V1 were localized using the reported induction of moving or stationary phosphenes, respectively. The vertex was stimulated as a control. Eight participants performed a motion discrimination task in which the direction of Gaussian dots in a random dot kinematogram was identified, and a detection task, in which the dots was detected regardless of motion, for isoluminant chromatic and luminance stimuli. Thresholds were measured before cTBS and after stimulation for one hour. Results: For the motion discrimination task, cTBS stimulation of area hMT+ selectively impaired visual performance for both luminance and isoluminant chromatic stimuli in comparison to area V1 and vertex. Maximal effects occurred 3-18 minutes after stimulation, and by one hour performance had returned to baseline. For the detection task, no selective effect of cTBS was observed. Conclusion: Our study demonstrates that the use of cTBS impairs the function of area hMT+, providing further evidence that hMT+ is involved in the analysis of luminance defined global motion. Also, even though isoluminant color vision is poor for motion perception, we show that area hMT+ is contributing to residual chromatic motion at isoluminance. The results indicate a causal link between neural activity in area hMT+ and the perception of chromatic motion. This effect may be mediated by the response of M-cells to the chromatic stimuli, which feed into the motion pathway.

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26.427 **Interpolated visual features during apparent motion are represented in primary visual cortex**

Ariana Familiar[1](Ariana.familiar@dartmouth.edu), Edmund Chong[2], Won Mok Shim[1]; [1]Psychological and Brain Sciences, Dartmouth College, [2]New York University

While we perceive apparent motion (AM) between two static objects, our visual system interpolates an intermediate object, which is not present in the bottom-up input, on the illusory path of AM (Kolers & von Grunau, 1976; Hidaka et al., 2011). Recent neuroimaging studies using pattern classification methods demonstrate that the intermediate representations on the AM path can be decoded in regions of V1 retinotopically mapped to the AM path, suggesting that such interpolated features are represented at the earliest stages of cortical processing (Chong et al., 2011 VSS). However, it remains unclear whether the same population of neurons which encode this intermediate feature when it is actually presented are recruited during AM. Using fMRI and a forward encoding model, we examine the population-level orientation tuning in the region of V1 corresponding to the AM path while subjects view rotational AM induced by successive presentation of a right- (45o) and left-tilted (135o) grating at the upper and lower corners in the right visual field respectively. In the region of V1 corresponding to the AM path, we find clear orientation tuning functions that peak at the supposed intermediate orientation (0o), and gradually decrease as the distance from this orientation increases. Furthermore, this tuning is similar to the orientation tuning profile evoked by actual presentation of the intermediate grating on the AM path. Such orientation tuning is not found when subjects visually imagine the same stimuli, nor when the percept of AM is abolished by presenting the two gratings simultaneously. Our results suggest that non-stimulated region of early visual cortex (V1) represents features of a dynamic stimulus during AM even when those features are not present elsewhere in the bottom-up input, and therefore such features must be interpolated through top-down processing.

26.428 **Global versus local: double dissociation between MT+ and V3a in motion processing revealed by a TMS study**

Nihong Chen[1,2,3](cnh@pku.edu.cn), Peng Cai[1,2,3], Fang Fang[1,2,3]; [1]Department of Psychology and Key Laboratory of Machine Perception (Ministry of Education), Peking University, Beijing 100871, China, [2]Peking-Tsinghua Center for Life Sciences, Peking University, Beijing 100871, China, [3]PKU-IDG/McGovern Institute for Brain Research, Peking University, Beijing 100871, China

The functional properties of motion selective areas in human visual cortex, including V3A, MT+, and IPS (intraparietal sulcus) are far from being fully understood . To examine the functional specialization of these areas

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for global and local motion processing, we applied offline continuous theta-burst transcranial magnetic stimulation (TMS) aided by MRI-based neuronavigation to temporarily attenuate normal functioning of unilateral V3a, MT+ and IPS in different daily sessions. Vertex was also targeted as a control site. In each session, before and after TMS, subjects were asked to discriminate the global directions of two successive random dot kinematograms (RDKs), which consisted of 400 black dots within a circular area (9° in diameter). Four conditions were used: two motion coherence levels (100% or 40%) at two stimulus locations (left or right 9° horizontal eccentricity). We found that V3a stimulation selectively impaired discrimination of the 100% coherence motion, while MT+ stimulation selectively impaired discrimination of the 40% coherence motion. IPS stimulation impaired discrimination of both motion stimuli. All the impairments were specific to the stimuli presented contralaterally to the TMS site. Vertex stimulation did not lead to any change in motion discrimination. The double dissociation between the TMS effects on MT+ and V3a suggest distinctive roles of these two regions in motion processing. Under the 100% coherence condition, motion discrimination could be a local motion task because every dot moves in the same direction, so that local processing of motion signals is sufficient for identifying the direction of the RDK. However, under the 40% coherence condition, global processing is required to integrate different motion directions from many dots to form a coherent motion perception. Thus, our results suggest that MT+ and V3a dominate in global and local motion processing, respectively, and the outputs of these two areas may both project to IPS for further processing.

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26.429 Abnormal contrast saturation in V5/MT+ following damage to V1

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Residual vision, or blindsight, following damage to V1 appears to be particularly salient when high contrast moving stimuli are presented in the blind field. In healthy cortex V1 shows a steady increase in response with increasing luminance contrast. In comparison, V5/MT+ shows an early saturation effect with contrast, and even very low contrast levels elicit significant activation above baseline. Here we use fMRI to determine the pattern of response to contrast in V5/MT+ when V1 is damaged. Methods: 10 patients with adult-acquired homonymous hemianopia and chronic unilateral V1 damage and 9 age-matched controls were recruited. fMRI responses to drifting achromatic Gabor stimuli (5 or 8 degree diameter) were measured while participants performed a fixation task. Five contrast levels (1%, 5%, 10%, 50%, 100%) were presented to each hemifield (within the scotoma when in the blind field) in 3 scan runs (300s each). In separate 2-AFC psychophysical testing participants indicated whether a stimulus appeared in the first or second time-interval. Results: In the control group, V1 showed a linear increase in BOLD signal change with increasing contrast (R2=0.97). Response in V5/MT+ was best described by a logarithmic curve (R2=0.92), suggesting an early saturation effect. In patients, response in V5/MT+ in the damaged hemisphere showed a positive linear relationship with increasing contrast (R2=0.89), a pattern that correlated significantly with healthy V1 response in the sighted hemifield of patients, and control V1 response (r=0.30, p=0.03; r=0.92, p=0.02). There was no correlation with V5/MT+ response in patients' sighted hemifield, or to V5/MT+ in controls (r=0.17, p=0.24; r=0.78, p=0.12). Conclusions: V1 appears to be required for typical early-saturation responses to contrast in V5/MT+. When V1 is damaged, detection of stimuli within a scotoma improves as contrast increases. fMRI signal change in V5/MT+ in the damaged hemisphere also increases with contrast, according to a linear relationship.

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26.430 Dynamic neural encoding of component directions of transparently moving stimuli in cortical area MT

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The responses of cortical neurons elicited by two perceptually separable stimuli have been shown to follow the average of the responses elicited by the constituent stimuli. Such a scheme poses a challenge in segmenting two stimuli that differ only slightly, because averaging essentially takes away the information regarding the stimulus components. Here we investigate how spatially-overlapping stimuli moving transparently in slightly different directions are encoded in the middle-temporal (MT) cortex of macaque monkeys. Visual stimuli were two overlapping random-dot patches moving simultaneously within a static aperture in two directions separated by 60°. We recorded from 155 MT neurons in two monkeys as they performed a fixation task. Based on the response averaging, the predicted tuning curve of a MT neuron to our bi-directional stimuli typically had a single peak, located when the vector-averaged direction of the stimuli was at the neuron's preferred direction (PD). However, we found that the tuning curves of half of the neurons deviated from the averaging prediction. About 1/3 of the neurons showed tuning curves that were biased toward one of the component directions. The tuning curve averaged across these neurons had a single peak located when one of the component directions was near the PD. For another 1/7 of the neurons, they showed two separate peaks in their tuning curves, which peaked when either one of the component directions was near the PD. Interestingly, these direction tuning curves evolved gradually over time. During the initial response period of ~50 ms, the tuning curve was symmetric with a single peak. Over a period of an additional 50 ms, the response tuning was either biased toward one component direction, or split into two peaks. These nonlinear response properties of MT neurons may manifest a dynamic solution of segmenting slightly different component directions of transparently moving stimuli.

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26.431 Battenberg summation reveals larger psychophysical receptive fields for motion signals

Thomas McDougall[1](mcdout01@student.uwa.edu.au), J. Edwin Dickinson[1], David R. Badcock[1]; [1]School of Psychology, University of Western Australia

Classic area summation studies increase the overall size of the stimulus to increase signal area. The results of this approach can be obfuscated by summation of additional internal noise as stimulus size increases. This study re-evaluated summation extent for motion signals using a Battenberg stimulus (Meese, 2010) designed to circumvent internal noise changes by holding display size constant. In the checkerboard stimulus, the size of the checks containing signal (3 cycles/deg luminance-modulated drifting sinewave gratings) can be varied to measure dependence on signal area. Experiment 1 used either, signal checks alternating with uniform, mean luminance, checks (single-motion condition), or alternate checks containing gratings moving in opposite directions (opposing-motion condition). The latter tests whether summation extent changes when segregating regions based on motion direction. Contrast thresholds for motion detection were measured using a 2IFC task in conjunction with adaptive staircase procedures in four observers, for a range of check sizes (0.7° to 3.2°). Results show summation over an area of at least 3.2° in size and this was found for both motion combinations, providing no evidence that the summation extent differs when segregating patterns based on motion direction, at the absolute detection threshold. However, high-contrast stimuli increase surround suppression (Tadin, Lappin & Blake, 2003). Therefore, Experiment 2 employed a suprathreshold, 20% contrast, pedestal in the signal checks in both intervals of the 2IFC; a contrast discrimination task. The aim was to determine whether differences in summation extent arise when segregation processes become more active. The results showed no dependence on check size, thus no evidence of summation for either the single-motion or opposing-motion stimulus for contrast discriminations well above threshold, across the range of sizes tested. This supports findings that motion summation diminishes at high-contrast, but provides no evidence that summation extent is dependent on motion combination, at suprathreshold levels.

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26.432 Interaction of color-defined and luminance-defined motion signals in human visual cortex

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It has been tested by motion aftereffect in a psychophysical study that color-defined and luminance-defined motion signals can interact. We tested direction selective aftereffects of color-defined and luminance-defined motions by psychophysics and fMRI to investigate its neural correlate. We used a ring-shaped stimulus with sinusoidal modulation, which moved in either clockwise (CW) or counter-clockwise (CCW) direction at the speed of 1/6 rotation-per-second; temporal frequency of the contrast modulation was 1 Hz, since the spatial modulation of the radial pattern was 6 cycles-per-round. There were four combinations for adaptation and test stimuli:

Saturday PM

color/luminance × CW/CCW. Color stimuli were adjusted subjectively to be isoluminant in each subject. The subject adapted to one direction of motion, defined by either color or luminance, during an experimental run. The duration of initial adaptation was 27 s, and the durations of top-up adaptation were randomly jittered between 12 ± 3 s. The test stimulus was randomly selected among the four combinations (color/luminance × CW/CCW), and was presented for 3 s between the continuous adaptation stimuli. Subjects performed a direction-discrimination task for the test stimulus, in addition to a fixation point task conducted throughout the run by counting the number of changes to a particular color. Psychophysical results were evaluated by the difference of reaction times to the test stimuli in the same and opposite direction of adapting stimulus, and cross-adaptation effects between color and luminance motions were confirmed. The direction selectivity of fMRI results was evaluated in each visual area ROIs with the difference in the BOLD-response amplitudes to the two directions of test-stimulus motion. Cross adaptation effects were found at 3-9 s after the onset of the test stimulus in most visual areas, while MT+ exhibited uncrossed aftereffect. The details and possible mechanisms of crossed adaptation effects will be discussed in the presentation.

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26.433 **Detection of phi and reverse-phi direction-specific responses using the steady-state VEP** Keiko Momose[1](k-momose@ieee.org), Alexandra Yakovleva[2], Anthony Norcia[2]; [1]Faculty of Human Sciences, Waseda University, [2]Department of Psychology, Stanford University

Noninvasive methods for probing direction-selective neuronal activity are of significant value for understanding human motion perception. Previous work using the Visual Evoked Potential has used adaptation to reveal direction-specific activity. Here we present a method that reveals motion mechanisms directly through a signature predicted by the motion energy model: motion energy detectors produce opposite-signed responses to phi and reverse-phi stimuli. We generated apparent motion displays comprised of an array of pairs of 1 deg adjacent square patches that were separated by 2 deg. One patch was flashed on and off at 5.14 Hz, the other at 6.0 Hz. Thirty-three pairs of patches were presented on a hexagonal lattice. Two white squares flashing on a gray background comprised the phi condition. Pairs consisting of one white and one black square comprised the reverse-phi condition. Experienced observers saw apparent motion at the difference-frequency (0.84 Hz). When presented side-by-side, synchronized phi- and reverse-phi displays appeared to move in opposite directions. EEG was recorded in nine normal vision adults using a 128-channel Geodesic Sensor Net with 0.1-50 Hz filtering. Fourier analysis was used to extract the response at the 0.84 Hz difference-frequency as an index of the spatio-temporal nonlinearity underlying the motion energy computation. As predicted by the motion energy model, the phase of difference frequency response for reverse-phi was shifted by 180 deg from that of the phi condition over occipital (O1, Oz and O2) and occipito-temporal cortex. The shift was also found at electrodes over the temporal lobe (near T3 and T4). Because the difference frequency component bears the signature expected of motion energy units, we consider it to be a direct marker of direction-selectivity.

26.434 **A direct measure of the role of attention in apparent motion** Francesca Pei[1,2](fpei@stanford.edu), Anthony Norcia[1]; [1]Psychology Department, Stanford, [2]Stanford Autism Center at Packard Children's Hospital

Two fundamentally different motion-processing mechanisms have been proposed, one "passive" and the other "active" (Cavanagh, 1991, 1992; Lu and Sperling, 1995, 2001). The passive system is a purely feed-forward process that utilizes a motion energy computation. The active system has been shown to be rely on attentive or feature-tracking mechanisms, and can account for motion percepts that are present in specialized stimuli where energy computations do not produce a specific direction. The extent to which active and passive mechanisms contribute to the processing of an "ordinary" stimulus is difficult to asses on the basis of perceptual judgments alone because one does not know which signal the subject uses to make the report and because it is difficult to determine what type of processing occurs in the absence of attention. Evoked Potential measures are ideal for studying this question because measurements of motion processing can be made equally well when attention is directed to motion or diverted from it. Arrays of small grating patches were presented to 12 adults at different spatial displacements and temporal offsets to produce either a vivid percept of apparent motion or a percept of flashing without motion. Two spatial separations of paired-flash targets were used (0.25 wavelength of the grating or 3 wavelengths). Patch onsets were sequential (apparent motion) or simultaneous (control). Observers either fixated a cross in the center of the screen and attended to the patches or performed a difficult letter discrimination task at fixation to divert attention. There was a small, but measurable effect of attention in the motion conditions, but a substantially larger one in the control conditions. In both cases attention effects were largest in the interval of 200 to 400 msec indicating that classic apparent motion displays engage processes that are largely independent of attention.

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26.435 **Behavioral consequences of perceptual decision-making in oculomotor brain structures** Sung Jun Joo[1,2,3](sjjoo@utexas.edu), Alexander C. Huk[1,2,3]; [1]Center for Perceptual Systems, [2]Institute for Neuroscience, [3]Department of Psychology, University of Texas, Austin, TX, USA

Neurons in several oculomotor brain areas (such as the lateral intraparietal area and superior colliculus) carry a multitude of signals. Even within a single task, individual neurons may exhibit responses related to visual/sensory events, decision formation, and saccade execution. Little is known about whether these signals interact and if such interactions have functional consequences. To test for interactions between decision-making and saccade execution signals, we used a behavioral dual-task paradigm that measured saccade reaction time (SRT) to a decision-irrelevant target while observers conducted a motion direction discrimination task. Observers (n=5) judged the direction (leftward versus rightward) of a random dot motion stimulus (of variable coherence; speed: 5 °/s). At the offset of the dots, a target appeared either left or right side of the fixation point (displaced by 20°). Observers were instructed to make an eye movement to the target as quickly as possible. After the eye movement, the direction of preceding dot motion was reported with a button press. We tested whether the SRT to the target was affected by the direction and strength of motion stimuli presented during the direction-discrimination task. Indeed, SRTs were faster on congruent trials (when the direction of motion was same as the saccade direction) compared to incongruent trials ($F_{1,4}=26.23$, $p<0.01$). Furthermore, SRTs progressively decreased with increased coherence ($F_{4,16}=5.45$, $p<0.05$). Thus, simple visually-guided saccades were affected by the ongoing buildup of activity related to decision formation, in a manner that was direction-selective and parametrically affected by motion strength. Our results are not due to the mere presence of motion stimuli because the dependencies on coherence and directional congruency were eliminated in a single-task (saccade only) control experiment. Revealing such interactions between decision making and saccade executions suggests that these two types of signals cannot be completely demixed in neural circuitry.

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26.436 **MEG Beta band oscillations index perceptual form/motion integration** Jean Lorenceau[1](jean.lorenceau@upmc.fr), Charles Aissani[1], Jacques Martinerie[1], Lydia Yahia Cherif[1], Anne-Lise Paradis[1]; [1]CRICM CNRS UPMC UMR7225

Scalp recordings of electrophysiological oscillations in humans reveal activity in different frequency bands correlated to perceptual, attentional, motor and cognitive processes. To probe the hypothetical roles of Gamma and Beta band activity in perceptual form/motion binding, we conducted a MEG study on 12 healthy participants using visual moving stimuli that, depending on subtle modifications of the distribution of luminance, could either be perceived as a whole square-shape moving along a Lissajou's figure (bound percept) or as two pairs of bars oscillating independently along horizontal and vertical axes (unbound percept). Each pair of bars moved at different frequencies (2.3 & 3Hz), so as to evoke different tagged cortical responses. After each trial, participants were to report their percept as bound, unbound (or unclassified). Randomizing the position of color coded responses required remapping the motor response on each trial, thus avoiding motor preparation that could contaminate the data. We report evoked tagged responses at the fundamentals and 1st harmonics of oscillations frequencies in parieto-occipital cortex independently from perception and identified significant differences in frontal sources at a 10.6 Hz intermodulation product for bound as compared to unbound percepts. Further, enhanced bilateral parietal Beta power (15-25 Hz) for bound as compared to unbound states and trial-by-trial classification of perception from Beta power suggest Beta oscillations provide a marker of perceptual states. Activity in the Alpha (8-12 Hz) and Gamma band (40-80 Hz), although significantly different during visual stimulation than during baseline, did not distinguish perceptual states. Our results indicate that Beta activity index perceptual states and favor the view that Beta oscillations serve to facilitate the long-range communication involved in integrating moving elements into a global object motion across both hemispheres.

Acknowledgement: ANR -08-BLAN-0250-01

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26.437 **The effect of attention and dot coherence on fMRI responses to 3D structure-from-motion** Cheng Qiu[1](qiuxx077@umn.edu), Daniel Kersten[1], Cheryl A. Olman[1]; [1]Psychology, University of Minnesota

Humans can easily perceive the three-dimensional structure of a rotating object from a group of moving dots that are fixed relative to this rotating structure. Previous research has suggested that area V1 provides spatially localized motion measurements to MT, where they are integrated resulting in a coherent 3D interpretation (Bradley et al., 1998). However, it is not clear how external noise and attention may influence cortical responses. We used fMRI to measure the BOLD activity in visual cortex while subjects viewed structure-from-motion (SfM) stimuli of varying coherence in blocks. Subjects performed either a fixation task (unattended condition) or a shape recognition task (attended condition). Novel 3D shapes were generated using perturbations in spherical harmonics. External noise was induced by aligning 0%, 33%, 66%, or 100% of the moving dots with the structure, while the rest were shifted randomly a small amount away from the structural surface. Low-level stimulus features such as dot density, velocity vectors and static shape information were tightly controlled. We found that only intermediate and higher-level visual areas were significantly modulated by coherence level of the SfM stimuli. Responses in the early/mid-/higher-level visual areas were all influenced by attention. Visual areas hV4, LO1 and LOC showed interactions between attention and dot coherence. Responses of cortical areas further away from the retinal input showed greater dependence on the coherence level. Attention to the 3D structure also increased response dependence on coherence, and enlarged dynamic range of BOLD responses to variations in coherence.

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26.438 **FMRI correlates of visual motion processing in hearing and deaf adults** Alexandra Levine[1](atl507@york.ac.uk), Shradha Billawa[1], Laura Bridge[1], Sally Clausen[1], Mark Hymers[2], Heidi Baseler[3]; [1]Department of Psychology, University of York, York YO10 5DD, UK, [2]York Neuroimaging Centre, University of York, York, YO10 5DD, UK, [3]Centre for Neuroscience, Hull York Medical School, York YO10 5DD, UK

Lack of auditory stimulation experienced by the congenitally, profoundly deaf can lead to greater visual sensitivity, particularly to peripheral visual motion (Buckley et al. 2001). Previous research attributes this advantage in part to greater recruitment of area V5 in deaf than hearing individuals (Bavelier et al. 2001). However, recent data have shown that structural differences as early as the retina correlate with peripheral motion sensitivity in deaf and hearing adults (Codina et al. 2011). The current study evaluated neural responses in early visual cortical areas and investigated the relationship between cortical activation and visual performance differences in deaf and hearing adults. Participants included fourteen hearing and four congenitally, profoundly deaf adults without visual deficits. Motion direction discrimination thresholds were measured in each individual using an optic flow stimulus restricted to the central (0-5˚) or peripheral (40-72˚) visual field. FMRI responses were measured from each participant while viewing retinotopic mapping and optic flow motion stimuli. Peripheral stimuli extended out to +/-72˚ to include the far peripheral visual field, where visual sensitivity differences are greatest in the deaf. Activity within visual areas V1 and V5 was measured and correlated with psychophysical thresholds for each individual. V1 response magnitude in the far-peripheral representation was greater in deaf than hearing participants. Peripheral motion direction discrimination thresholds in all participants were significantly correlated with V5, but not V1 activation. V5 activation correlated with behavioural motion sensitivity in optic flow tasks in all participants, supporting this area's role in motion processing. In addition, deaf participants exhibited greater activation in far-peripheral representations in V1, advocating early visual pathway changes in response to hearing loss. Motion sensitivity did not correlate with V1 responses, however, suggesting that changes in early visual pathways may not mediate improved sensitivity for all types of peripheral motion tasks.

Perception and action: Neural mechanisms

Saturday, May 17, 2:45 - 6:45 pm
Poster Session, Pavilion

26.501 **Sensorimotor and cognitve changes following exercise with and without subconcussive head trauma** Stuart Red[1](stuart.d.red@uth.tmc.edu), Alex Hacopian [1], Anne Sereno[1]; [1]Neurobiology and Anatomy, University of Texas at Houston

Repeated sub-concussive head trauma is common in many popular sports, however the cognitive effects are not well studied. Many of the studies that have failed to find cognitive differences following subconcussive head blows have used more formal and complicated cognitive testing that lacks sensitivity to more subtle changes, is vulnerable to substantial practice effects, and is susceptible to malingering. Further complicating the detection of any subtle deficits in cognitive function related to subconcussive head blows is the well-known cognitive enhancement related to exercise. Our lab has developed a novel tablet measure based on eye-tracking tasks that may prove more sensitive in detecting cognitive changes. The propoint task is a more reflexive task and involves making a movement to a stimulus, while the anitpoint task tests voluntary/executive function and involves making a motor movement in the opposite direction of a stimulus. Using this novel measure, we measured sensorimotor and cognitive functioning in professional boxers performing boxing workouts either with (spar workout) or without (bag workouts) head blows. We compared performance changes across two different time intervals: (1) immediate- before and after a workout; and (2) delayed- before and 24-48 hours after a workout. We find significant improvements (faster times) on both tasks immediately following a vigorous bag workout. In contrast, subjects show no improvement on either task immediately following a spar workout. Furthermore, 24-48 hours following a workout, subjects show significant improvement on both tasks with a bag workout, whereas they show significant slowing on the antipiont task with a spar workout. These results indicate that exercise alone may be immediately improving performance on these tasks, exercise with subconcussive head blows obliterates this improvement. Further, 24-48 hours later, a bout of exercise without subconcussive blows continues to show significant beneficial effects whereas exercise with subconcussive blows results in significant slowing.

26.502 **Rhythmic oscillations of visual contrast sensitivity triggered by voluntary action** Alice Tomassini[1](alice.tomassini@iit.it), Marco Jacono[1], Giulio Sandini[1], Donatella Spinelli[2], Concetta Morrone[1, 3]; [1]Department of Robotics, Brain and Cognitive Sciences, Fondazione Istituto Italiano di Tecnologia, Via Morego 30, 16163 Genova, Italy, [2]Department of Human Movement, Social and Health Sciences, Università degli Studi di Roma "Foro Italico", Piazza Lauro De Bosis 15, 00135 Roma, Italy, [3]Department of Translational Research on New Technologies in Medicine and Surgery, University of Pisa, via San Zeno 31, 56123 Pisa, Italy

Spontaneous oscillations of brain activity can be synchronized by external stimuli, or by allocation of attention, and this can lead to small synchronous modulation of visual perceptual performance (Landau and Fries, 2012, Thut et al., 2012). Increasing evidence shows that motor processing affects perception in many ways. Here we investigated whether performing an action can generate rhythmic oscillations of visual contrast sensitivity. We measured visual contrast sensitivity for orientation discrimination of briefly (33 ms) displayed Gabors (spatial frequency 1 c/deg; eccentricity 7.5 deg to the left or to the right of fixation) tilted at ± 45 degrees and embedded within dynamic noise (refreshed every frame) that lasted more than 3 s. Participants were asked to execute reaching movements towards the display behind an occluder (which hid the movement: open loop) in the same direction of the position of the right visual target. The visual stimuli were randomly presented at different times with respect to the movement (from ~ 500 ms before to ~ 300 ms after movement onset) and for each subject more than 2000 trials were collected to obtain stable psychometric functions densely sampled over time. Visual contrast sensitivity for both eccentricities varied by about 0.2 log-units, oscillating with periodicity in the theta range (~ 5 Hz). Interestingly, the oscillations in visual performance began before movement onset, suggesting that a motor preparatory signal might be responsible for synchronizing activity in primary visual areas. The present results reinforce growing evidence that sensory and motor functions are strongly interconnected, demonstrating that motor processing can modulate very early sensory function, such as the sensitivity to visual contrast, and suggesting that sensory-motor integration might be, at least partly, mediated by phase modulations of brain rhythmic activity.

Saturday PM

26.503 **“On the same wavelength”: interpersonal alpha synchronization improves visual-motor coordination** Aleksandra Sherman[1](aleksandrasherman2014@u.northwestern.edu), David Brang[1], Casey Noble[1], Marcia Grabowecky[1], William Horton[1], Vernon L. Towle[2], James X. Tao[2], Satoru Suzuki[1]; [1]Psychology Department, Northwestern University, [2]Neurology Department, University of Chicago

When two people are engaged in a conversation and feel they understand each other's perspectives, they often describe their experience as “on the same wavelength.” During these interactions, people tend to automatically mirror one another's gestures and facial expressions. It has recently been shown that this overt behavioral mimicry is correlated with increased interpersonal neural synchrony, especially in alpha-band (~10Hz) oscillations. Building on this line of work, we investigated a causal link between interpersonal alpha-band synchronization and visually guided behavioral coordination. Using electrocorticography we verified that amplitude-modulated sounds generate widespread cortical alpha-band oscillations (well beyond the auditory cortex) phase-locked to the amplitude modulation. We therefore used amplitude-modulated sounds to generate interpersonally synchronized or desynchronized alpha-band oscillations. A pair of individuals sat face-to-face and tried to finger-tap as synchronously as possible by visually observing each other's tapping behavior. On each trial, the interacting individuals were either synchronized in their alpha-band oscillations (e.g. heard identical auditory alpha rhythm) or desynchronized in their alpha oscillations (e.g. heard slightly different auditory alpha rhythms, generating alpha-band oscillations that are continuously phase-shifting between the two individuals). We show that the pair's visual-motor coordination was enhanced (i.e., they tapped in greater synchrony) when their alpha oscillations were synchronized. We verified that this effect is not explained by direct entrainment of tapping to the rate or phase of amplitude-modulated sounds. We further showed that hearing the same alpha-band amplitude-modulated sound does not increase the temporal correlation between individuals' responses to the same computer-generated rhythm. Taken together, these results suggest that interpersonal alpha-band neural synchronization facilitates visual processes that guide interpersonal visual-motor coordination. Thus, when people are truly “on the same wavelength,” they have improved visual coordination as a result.

26.504 **Temporal Stability of Reference Frames in a 3D Reaching Task in Monkey Area V6A** Patrizia Fattori[1](patrizia.fattori@unibo.it), Kostas Hadjidimitrakis[2,1], Federica Bertozzi[1], Rossella Breveglieri[1], Claudio Galletti[1]; [1]Department of Pharmacy and Biotechnology, University of Bologna, Piazza di Porta San Donato 2, Bologna 40126, Italy., [2]Department of Physiology, Monash Vision Group, Monash University, Melbourne, Victoria 3800, Australia.

Neurons in the medial posterior parietal area V6A of macaques show spatial modulations during all the phases of an instructed delay reaching task towards visual targets placed either in a frontal plane, or in 3D space (Fattori et al., Eur. J. Neurosci 2005; Hadjidimitrakis et al., Cereb Cortex 2013a). Furthermore, shortly before and during the execution of reaching movements towards foveated targets that started from different hand positions, V6A neurons were found to encode targets either in a ‘pure’ body-centered frame of reference, or in mixed body/hand-centred coordinates (Hadjidimitrakis et al., Cereb Cortex 2013b). In contrast to nearby areas such as the Parietal Reach Region (PRR, Chang and Snyder, PNAs 2010), no significant evidence of ‘pure’ hand-centred coding was found in V6A. Here, we investigated the presence of hand-centred coding in earlier epochs of the task, i.e. immediately after target fixation and in the subsequent early part of the delay period and examined whether the reference frames in individual neurons are stable across the task epochs. We present data from single neurons recorded from V6A in two Macaque monkeys and report no evidence of hand-centred coding also in the earlier phases of the task. Shortly after target fixation and throughout the early delay period, the population of V6A neurons used either body-centred, or mixed body/ hand-centred reference frames. Most of the cells spatially tuned across multiple epochs showed consistent reference frames during the task progress. Rather surprisingly, as movement onset approached, a small but significant proportion of cells shifted from mixed body/ hand-centred frames to ‘pure’ body-centred coordinates. These findings suggest that in V6A the signal of target position relative to the hand is more prevalent shortly after fixation, and is gradually transformed to yield more egocentric representations in the pre- and movement epochs.

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26.505 **Neural substrates for allocentric-to-egocentric conversion of target representation for memory-guided reach** Ying Chen[1,2](liuc@yorku.ca), J. Douglas Crawford[1,2,3,4,5]; [1]Center for Vision Research, York University, [2]School of Kinesiology and Health Science, York University, [3]Department of Psychology, York University, [4]Department of Biology, York University, [5]Canadian Action and Perception Network

Allocentric cues can be used to encode target location in visuo-spatial memory (Chen et al., 2011; Obhi & Goodale, 2005), and the allocentric representation is converted into egocentric representation at the first possible opportunity for reach (Chen et al., 2011). However, neural substrates for allocentric-to-egocentric conversion have not been explored yet. Here we used fMRI to investigate brain areas involved in allocentric-to-egocentric conversion for memory-guided reach. Ten participants reached towards a remembered target location represented in allocentric frames of reference. Participants fixated a central point while a target was presented along with an allocentric cue for 2s. The concurrent presentation of target and cue was followed by a delay period (6s), after which an auditory instruction (“Same cue” or “Different cue”) instructed participants that the allocentric cue would re-appear at the same location, allowing for a conversion of target location from allocentric to egocentric, or at a different location, requiring participants to wait for the re-appearance of the cue before they knew the target location to reach. A second delay period (10s) followed the auditory instruction. Next, the allocentric cue re-appeared for 2s and was followed by the go-signal to reach towards the remembered target location relative to the location of the re-displayed allocentric cue. We hypothesized that brain areas involved in allocentric-to-egocentric conversion would show higher activation when the allocentric representation of target location could be turned into an egocentric representation. This would be revealed by higher activation in the “Same cue” as compared to the “Different cue” condition during the second delay period. This pattern was revealed in bilateral dorsal precuneus, left angular gyrus and bilateral inferior frontal gyrus. Our results suggest that posterior parietal cortex and frontal areas play a critical role in converting allocentric representation of target location into egocentric representation for reach planning.

Acknowledgement: CIHR and Canada Research Chair Program

26.506 **The event related potential technique and microstate analysis of memory guided and visually guided movements.** Darian Cheng[1](dar.t.cheng@gmail.com), Krista Fjeld[1], Gordon Binsted[1]; [1]University of British Columbia

While behavioral protocols have primarily been used to examine the use of memory in human movement (Elliott & Madalena, 1987; Westwood, Heath & Roy, 2003), more recent examinations have involved more imaging techniques to determine the underlying brain processes that facilitate this function (Krigolson et al., 2011). This study examines the neural correlates associated with memory guided and visually guided reaching movements using electroencephalography (EEG). Participants performed manual aiming movements to targets under varying visual feedback (full-vision & no-vision) and delay (2 or 5 s) conditions. In experiment 1, conditions were randomized across trials while in experiment 2 conditions were blocked. Using the event related potential (ERP) technique we observed the visually evoked potentials (VEPs) associated with the preview of the target as well as movement related potentials associated with movement execution. The behavioral findings from the study replicated the typical advantage of having visual feedback i.e., greater accuracy and precision with vision. Additionally, the electrophysiological data revealed differences in brain potentials across vision conditions during target encoding and movement execution within the blocked protocol. Notably, brain potentials over parietal electrodes were suppressed in memory guided reaches as compared to visually guided reaches. Moreover, a longer delay period in no-vision revealed greater suppression of brain potentials. A micro-state analysis (i.e., Cartool software) involving the full electrode montage was used to examine the clustering of activity across the scalp over time. The results of this analysis showed differences in microstate duration across vision conditions that not only reinforce the basic ERP findings but also providing greater clarity on the potential underlying neural processes sub-serving manual aiming.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada (NSERC)

See page 3 for Abstract Numbering System

26.507 **Correct action affordance among unattended objects reduces their competition for representation in V4**

Erica Wager[1](ewager@email.arizona.edu), Glyn W. Humphreys[2], Paige E. Scalf[1]; [1]Department of Psychology, College of Science, University of Arizona, [2]Department of Experimental Psychology, University of Oxford

Real world objects do occur in an interactive context rather than in isolation. Previous evidence suggests that the neural processing of multiple visual objects changes as a function of their action affordances; specifically, objects evoke greater visual signal when positioned correctly for interaction (Roberts et al., 2010). This has functional consequences for parietal lobe patients who experience visual extinction. An ipsilesional visual item is less likely to extinguish a contralesional visual item if the two items are positioned to interact with one another (e.g., corkscrew going into the top of a wine bottle; Riddoch et al., 2003). Roberts, Riddoch, Humphreys and colleagues posit that objects positioned appropriately for action are likely to form a single functional unit and less likely to compete for representation within the visual system (Duncan & Desimone, 1995). Here, we use fMRI to directly test this hypothesis. We presented participants with pairs of semantically related objects (e.g., a frog and a wand) in the upper left visual field (center to center separation = 2.2 degrees). Objects were either positioned with correct (wand located to the upper right of the frog) or incorrect (frog located to the upper right of the wand) action affordances. We assessed competitive interactions between the items by comparing the signal they evoked when presented simultaneously (likely to compete) vs. when presented sequentially (unlikely to compete). Items were less likely to compete for representation in V4 when they were presented in the correct action affordance (Sensory suppression index (SSI) = .155) than when they were presented in the incorrect action affordance (SSI=.358, p <.05). Objects did not compete for representation in V1 and V2 (whose cells' receptive fields are small enough to permit their independent representations). These data suggest that knowledge of objects and their interactions create a larger "action unit" that modulates early visual processing.

26.508 **Neural bases of planning and execution of functional grasps: an fMRI study**

Lukasz Przybylski[1](przybluk@gmail.com), Szymon Bidula[1], Mikolaj Pawlak [1,2], Gregory Kroliczak[1]; [1]Action and Cognition Laboratory, Institute of Psychology, Adam Mickiewicz University, Poznan, Poland, [2]Department of Neurology and Cerebrovascular Disorders, Poznan University of Medical Sciences, Poland

Neuropsychological and neuroimaging evidence implicates the praxis representation network (PRN) of the left cerebral hemisphere in mediating tool use skills. Whether or not this network is engaged in the planning of function appropriate grasping is unknown, though often assumed in neuroimaging works. Such assumptions are inconsistent with neuropsychological evidence for independent representations of grasp attributes and functional actions (Randerath et al. 2009). In this study we aimed to establish the basic neural underpinning of the planning and execution of visually guided functional grasps. Methods: Using standard neuroimaging parameters and an optimized event-related design (Kroliczak & Frey, 2009), we investigated this issue while 12 right-handed participants performed the following four tasks with their dominant hands: (1) planning of a functionally appropriate grasp of a tool (2) planning of a grasp of a non-tool control object matched for complexity (3) pantomimed execution of a just planned functional grasp, and (4) pantomimed execution of a just planned control grasp. The stimuli were high-resolution pictures of tools and non-tool graspable objects presented at three different angles (0, 135, and 225 degrees) in their foreshortened perspectives, thus convincingly emulating 3D viewing. Results: Tool vs. non-tool grasp planning revealed greater involvement of the bilateral parieto-frontal network, with the supramarginal, caudal middle temporal and fusiform gyri activity primarily/only on the left. Notably, planning of the most demanding grasps of tools (vs. simple grasps of control objects) engaged only left PRN. Conclusions: The observed parieto-frontal involvement cannot be accounted for either by object complexity differences or increased task demands (including end-state comfort effects) because we did not observe any significant differences between the two tasks during their execution. Thus, the greater engagement of the left-hemisphere praxis representation network for planning functional grasps reveals a genuine effect of an early affordance-based representation of tools.

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26.509 **Tool use and representations of reachable space in the superior parietal lobe**

Kristen Macuga[1](Kristen.Macuga@oregonstate.edu), Scott Frey[2]; [1]School of Psychological Science, Oregon State University, [2]Department of Psychological Sciences, University of Missouri

Monkey electrophysiology suggests that manipulating distant objects with a stick induces a remapping of extrapersonal (out of reach) into peripersonal (within reach) space. Neuropsychological research has shown that when parietal patients with peripersonal neglect point with a stick, their impairment extends into extrapersonal space. This remapping does not occur when a laser pointer is used, presumably because, unlike the stick, it is ineffective at manipulating the distant environment. fMRI evidence suggests that superior-parietal occipital cortex (SPOC) codes peripersonal space. If SPOC codes objects within reach (regardless of distance), then it should show increased activity when performing with a tool that can affect distant objects (stick) vs. a tool that cannot affect distant objects (laser pointer). In an attempt to clarify this issue, objects in our fMRI-based reciprocal aiming task were always presented beyond reach of the hand, and participants used either a stick or laser pointer matched for torque and dynamics. Movement time (MT) was analyzed along with the BOLD responses as a function of the index of difficulty (ID). We found that MT increased linearly with ID, thus obeying Fitts' law. MTs did not differ between the stick and laser pointer, nor was there an interaction between tool type and MT suggesting that, although differing in their end-effector properties, the dynamics of our stick and laser pointer were well matched. However, we failed to find support for the hypothesis that SPOC is involved in representing reachable space. Instead, anterior superior parietal lobe responded selectively for actions performed with a stick, which physically extended the participant's reach, as opposed to a laser pointer, which did not. We suggest that this region of the human brain supports dynamic representations of reachable space.

26.510 **Hand-dependent and hand-independent cerebral asymmetries in the praxis representation network during planning of functional grasps**

Gregory Kroliczak[1](krolgreg@amu.edu.pl), Lukasz Przybylski[1], Szymon Bidula[1], Mikolaj Pawlak [1, 2]; [1]Action and Cognition Laboratory, Institute of Psychology, Adam Mickiewicz University, Poznan, Poland, [2]Department of Neurology and Cerebrovascular Disorders, Poznan University of Medical Sciences, Poland

When planning function-appropriate grasping actions with their right hands, right-handers show left-lateralized cerebral activity in caudal temporal, inferior parietal, and middle frontal cortices, especially when demanding visuomotor transformations are required. We investigated whether or not similar asymmetries are evident when such actions are planned with the use of the left hand. Methods. Brain activity was measured in an event-related design (cf. Kroliczak & Frey, 2009) while 12 right-handed participants performed the following tasks with their dominant, and non-dominant hands: (1) planning functionally-appropriate grasps directed at tools, (2) planning control grasps directed at non-tool objects matched for complexity, (followed by (3) pantomimed execution of the functional and (4) pantomimed execution of control grasps). These actions were cued by high-resolution images of graspable tools and non-tool objects presented at three different angles in their foreshortened views, emulating 3D viewing. Only planning-related effects are considered here. A paired-samples T-test was used to compare activity from contrasts of planning functional vs. control grasps for the right, and for the left hand (independent of the required hand rotation). Results. Except for significantly greater suppression in the left, and significant increases of activity in the right sensorimotor cortices for the non-dominant hand, the networks mediating planning of function-appropriate grasping actions for either hand did not differ. Interestingly, the increases of activity in the caudal middle temporal, fusiform, and middle frontal gyri were exclusively left lateralized, independent of the hand used. Conclusions: These results provide evidence that regions involved in the sensorimotor control of hand actions participate in the planning of function-appropriate grasps only for the non-dominant hand. Moreover, although areas involved in motor cognitive functions such as grasp planning may show some hand-specific modulations, the hand-independent representations of these skills are located primarily in the left hemisphere, and contribute to early affordance-based processing of tools.

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26.511 **Visual information shapes the dynamics of cortico-basal ganglia pathways during perceptual response selection and inhibition** Sara Jahfari[1,2](sara.jahfari@gmail.com), Lourens J. Waldorp[2], K. Richard Ridderinkhof[1,2], H. Steven Scholte[1,2]; [1]Cognitive Science Centre Amsterdam, University of Amsterdam, The Netherlands, [2]Department of Psychology, University of Amsterdam, The Netherlands

Action selection often requires the transformation of visual information into motor plans. When visual information is transformed fast, successful response inhibition might require suppression of both the prepared muscle activity and processing of visual input. We examined how the quality of visual information influences classic fronto-basal ganglia routes associated with response selection and inhibition. Human fMRI data was collected from a stop-task with faces containing low-, high-, or all spatial frequencies. Using the drift-diffusion model for decision-making, removal of spatial frequencies was found to slow the rate of information accumulation and reduce cautiousness. On go-trials, effective connectivity analysis showed action selection to emerge through a cortico-basal ganglia network with projections from both visual and prefrontal cortex into the "direct" and "indirect" pathways of the basal ganglia. Across conditions, slowed accumulation increased connectivity from both dorsolateral prefrontal cortex and fusiform face area into the putamen. Concurrently, presupplementary motor area connectivity into putamen, and lateral occipital connectivity into subthalamic nucleus was weakened to allow lowered criteria for correct decisions. During stop trials, both visual and prefrontal cortex projected into the "hyperdirect" and "indirect" pathways of the basal ganglia. Most notably, only when a stop signal followed unfiltered faces (i.e., with the highest drift rate) the optimal model contained additional connections from prefrontal to visual cortex. Further inspection related stronger prefrontal-visual connectivity to faster inhibition times. Therefore, prefrontal to visual cortex connections might suppress the fast flow of visual input for the go task, such that the inhibition process can finish before the selection process. Together, these results provide compelling insights into how visual information interacts with fronto-basal ganglia systems, and further specify how selection and inhibition processes emerge within the basal ganglia through top-down adjustments from prefrontal-, and bottom-up evaluations from visual cortex.

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26.512 **Revisiting touch observation in anterior parietal cortex: vicarious activation in somatosensory cortex?** Annie Chan[1](chanannie@mail.nih.gov), Chris Baker[1]; [1]National Institute of Mental Health

Recent studies have reported that seeing a hand being touched elicits strong of activation in somatosensory cortex (SI, SII), suggesting that these regions may play an important role in understanding other's experiences. However, prior research has not systematically mapped out the location of these activations or examined their functional specificity. To understand the topography of visual hand representations in parietal cortex and the nature of these representations, we used fMRI to investigate visual responses to the observed touch of a hand. First, we carefully identified SI and SII using anatomical and independent functional localizers. We then compared responses to the sight of a static hand being brushed compared to brush alone. We found that observing a hand being brushed elicited activation in superior and inferior parietal cortex, but not the hand representation in SI and SII. We then characterized the functional properties of these parietal regions in three separate experiments. Experiment 1 revealed that while the presence of both a hand and a brush was necessary, observation of actual touch was not needed, brushing near hand was sufficient. Further, there was no difference between observing a left or a right hand being touched. Experiment 2 showed no effect of perspective, with equivalent responses to egocentric and allocentric views of hands. Finally, Experiment 3 revealed some selectivity for the form of the object and the nature of the movement with reduced responses to a hand being "brushed" by a laser beam, a foot being brushed, and finger movement. Overall our results question the role of somatosensory cortex in understanding other's experiences. Instead, we find that observing touch activates regions in parietal cortex, but not somatosensory cortex of hand, with properties that reflect the interaction between a hand and an object, consistent with an involvement in visually guided action.

Acknowledgement: Intramural research program of NIH

26.513 **Are You Gonna Eat That? (Your brain says "yes," but your body says "maybe.")** Jason Flindall[1](jason.flindall@gmail.com), Kayla Stone[1], Claudia Gonzalez[2]; [1]Neuroscience, Faculty of Arts and Sciences, University of Lethbridge, [2]Kinesiology, Faculty of Arts and Sciences, University of Lethbridge

Evidence from recent neurophysiological studies on non-human primates as well as from human behavioural studies suggest that actions with similar kinematic requirements (i.e., reach-to-grasp) but different end-state goals (e.g., grasp-to-place versus grasp-to-throw) are supported by different neural networks. However, it is unknown whether these different networks supporting seemingly similar reach-to-grasp actions are lateralized, or if they are present in both hemispheres. Recently, we provided behavioural evidence suggesting they are lateralized to the left hemisphere. Specifically, we observed that when participants used their right hand their maximum grip aperture (MGA) was smaller when grasping-to-eat food items compared to when grasping-to-place the same items. Left-handed movements show no difference between tasks. Given that grasp-to-eat actions are fundamental for human survival, we interpreted this finding as a potential driver of population-level right-handedness. In the present study we investigate whether the differences between grasp-to-eat and grasp-to-place actions are driven by an intent to eat the food, or if placing it into the mouth (sans ingestion) is sufficient to produce asymmetries. Twelve right-handed adults were asked to reach-to-grasp food items to either a) eat the item, b) place it in a bib below his/her chin, or c) briefly place the item between his/her lips, then spit it into a nearby bin. Participants performed each task with large/small food items, using their dominant and non-dominant hands (hand/task order counterbalanced). MGAs (measured by an Optotrak camera system) were analyzed using a 2 (Hand; right/left) x2 (Size; small/large) x3 (Task; eat/place/spit) ANOVA. Our results replicated our previous finding of smaller MGAs for the eat condition during right-handed grasps only. Furthermore, MGAs in the eat and spit conditions did not significantly differ from each other, suggesting that eating and bringing a food item to the mouth both utilize similar motor plans, likely originating within the same neural network.

26.514 **2D vs 3D visualization modalities and their effects on motor related potentials** Teresa Sollfrank[1](teresa.sollfrank@uni-wuerzburg.de), Daniel Hart[2], Rachel Goodsell[3], Jonathan Foster[3], Andrea Kübler[1], Tele Tan[2]; [1]Institute of Psychology, University of Würzburg, 97070 Würzburg, Germany, [2]Department of Mechanical Engineering, Curtin University, Perth, Western Australia, [3]School of Psychology and Speech Pathology, Curtin University, Perth, Western Australia & Neurosciences Unit, Health Department of WA

Objective: When pathways for normal motor function are interrupted (e.g. after stroke), brain-computer interfaces (BCI) can be used as an alternative channel for communication by translating brain signals measured with electroencephalography (EEG) [1] and/or to influence brain plasticity processes to induce recovery of normal motor control [2]. Especially after neural injury local cortical connections are continuously reorganized and sensorimotor rhythm-based BCIs might be able to guide newly sprouting axons to the appropriate cortical regions by repetitive motor imagery practice [3]. This study investigated if feedback (2D vs. 3D visualisation) can amplify motor related potentials during motor imagery. We hypothesize that three dimensional, sensory richer feedback might be more effective during instrumental conditioning, resulting in more pronounced event related desynchronisation (ERD) of the mu (10-12Hz) and beta (20 Hz) bands over the sensorimotor cortex. Methods: 15 healthy, BCI naïve participants were instructed to watch attentively videos of seven different left and right arm movements on a True3Di monitor (2D and 3D, using stereoscopic glasses) and to replicate these movements subsequently by motor imagery. EEG signals were recorded from a grid of 40 Ag/AgCl scalp electrodes. Results: In Fig. 1 Left and Right, increased ERD peaks are present during motor imagery after 3D feedback at electrode position CP3 and CP4. Largest desynchronisation in the mu band power was elicited after 3D feedback (left:-8.3 dB; right: -8.5 dB from baseline; 2D left: -4.9 dB; right: -8.3 from baseline, Fig. 1 Middle). Conclusion: Motor imagery offers a promising technique for motor rehabilitation [4]. These results support the hypothesis that the choice of feedback modality can have significant effects on motor-related potentials. By inducing changes in the features of brain activity, 3D BCI protocols might be able to guide plasticity to promote recovery of motor function [5].

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Attention: Capture

Saturday, May 17, 2:45 - 6:45 pm
Poster Session, Pavilion

26.515 The Effects of Spatial and Temporal Predictability on Reaction Time in a Continuous Performance Task: Predicting Where but Not When.

Benjamin DeCorte[1](bdecorte@villanova.edu), Amanda van Lamsweerde[2], Melissa Beck[2]; [1]Department of Psychology, Villanova University, [2]Department of Psychology, Louisiana State University

In everyday life, we must extract information from the environment in order to generate predictions about future events and adjust behavior accordingly. Spatial and temporal aspects of objects in our environment can be particularly useful. Therefore, it is important to understand how spatial and temporal predictability can be learned in order to optimize behavior. Our study used a continuous performance task where a target (a red square) appeared in one of four possible locations, after one of four possible inter-trial-intervals (ITIs). Participants pressed a button as soon as they detected the target. The target location on trial n was associated with a particular location (spatial predictability) and ITI (temporal predictability) for the target on trial n + 1. Each target location was associated with a particular location and ITI (randomly determined for each participant before each block) for the following target appearance (e.g., if a target appeared in location a on trial n, there was a certain probability that it would appear in location b on trial n + 1). Across blocks of trials, we independently manipulated the degree of spatial and temporal predictability (low-25%, medium-65%, or high-90%). When target locations were highly predictive of the location of the next target, there was a significant reduction in reaction times (RT). However, high temporal predictability did not affect RT. Furthermore, there was no interaction between spatial and temporal predictability. Therefore, while participants were able to learn and use spatial information to predict where the next target would appear, they were not able to use this information to predict when the next target would appear.

26.516 Effects of implicit learning and explicit knowledge on the spatial suppression of irrelevant distractors

Yoolim Hong[1](y-hong1204@gmail.com), Rachael E. Gwinn[1], Andrew B. Leber[1]; [1]Psychology, The Ohio State University

Previous research in our lab has revealed that ignoring spatial locations that are likely to contain irrelevant, distracting information can be possible with subtle implicit learning manipulations (Leber, Gwinn & O'Toole, 2013, VSS). In that work, observers were unable to avoid interference by irrelevant distractors whose location was predicted by informative explicit spatial precues. However, when implicit spatial precues were introduced, the observers now demonstrated suppression of the irrelevant distractors, despite reporting no awareness of the implicit cues. In the present work, we asked the following: how does explicit knowledge interact with implicit learning in the suppression of irrelevant distractors? Will explicit knowledge prevent the implicit suppression of irrelevant information? To investigate this question, we modified our procedure using explicit dual arrow precues, which were presented simultaneously. In Experiment 1, a long arrow cued the most likely location of the target while a short arrow cued the most likely location of the distractor, both with 70% validity. Also, the same arrow that explicitly predicted the target location also implicitly predicted the distractor location with 70% validity. We found a robust target validity effect, demonstrating that observers used the long arrow to enhance the predicted target location. Critically, we also found a distractor validity effect, suggesting that implicit learning could occur in the presence of explicit cues. A second experiment confirmed that the suppression was selectively driven by the implicit cue; here, explicit dual cues were again used but now the implicit distractor cue was removed. Results again showed a robust target validity effect, but critically, the distractor validity effect did not emerge. Thus, while spatial suppression tends to occur only in the presence of implicit cues, simultaneous explicit cues – which are typically ignored – do not seem to interfere with or counteract the implicit learning effect.

Acknowledgement: NSF BCS-1027054 and US-Israel BSF 2009425 to ABL

26.517 Task-irrelevant attentional capture by salient expanding motion

Michiteru Kitazaki[1](mich@cs.tut.ac.jp), Yuta Murofushi[2], Jun Kawahara[3]; [1]Department of Computer Science and Engineering, Toyohashi University of Technology, [2]Graduate School of Engineering, Toyohashi University of Technology, [3]Department of Psychology, Chukyo University

Salient discontinuities in expanding optic flow induce attentional capture even when observers engage in feature-search mode in a different stimulus domain (Kawahara, Yanase, & Kitazaki, Journal of Vision 2012). We aimed to investigate whether global motion like as coherent optic flow is necessary or mere presence of a salient motion is sufficient for attentional capture to occur. In Experiment 1, the stimulus display consisted of 2,052 dots and a rapid stream of nontarget letters in the center. Observers searched for a green letter embedded in heterogeneously colored nontarget letters. The dots were divided into four square-regions (2x2 matrix, 18x18-deg each), so that the letter stream appeared in the intersection of the region borders. The bunch of dots expanded or contracted in each region for 100 ms at 300 ms before the presentation of a target. A control condition, under which the dots remained static, was also included. The results indicated that correct identification of the target was significantly impaired when the motions of four regions were contractions, suggesting that the expanding motion perceived locally around the central letter stream captures attention. In Experiment 2, the stimuli were identical to Experiment1 except that the dots in 6-deg diameter around the letters were deleted. We found that the accuracy for letter identification was impaired by four regions of expanding dots. This result suggests that local expanding motions capture attention. In Experiment 3, we presented a second-order motion of expanding or contracting circular contour by accretion and deletion of stationary dots (2,000 dots, contour diameter: min 6.9 to max 18.3-deg), and found the expanding second-order motion impaired letter-identification accuracy. This result suggests that the second-order motion can capture attention if the motion is expansion and sufficiently salient. We conclude that saliency of expanding motions is critical for the task-irrelevant attentional capture to occur.

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26.518 Biasing attention with a surprise non-singleton feature

Gernot Horstmann[1,2,3](gernot.horstmann@uni-bielefeld.de); [1]Center for Interdisciplinary Research, Bielefeld University, [2]Faculty of Psychology, Bielefeld University, [3]CITEC, Bielefeld University

The surprise capture hypothesis states that surprising or novel stimuli involuntarily attract attention. This has been empirically shown with the unannounced first presentation of a novel color during a visual search task, which eliminated set size effects, improved performance at short display durations, and induced validity effects. Most of these studies presented the novel color as a singleton, either at the position of the target or at the position of a distractor. While there are good reasons to discount the role of singleton capture in these experiments, it seems still desirable to test the surprise capture hypothesis for non-singleton novel stimuli. This was done in the present study by unexpectedly changing the color for half of the stimuli in the last ("critical") trial of a visual search task. To assess the biasing of attention towards the novel non-singleton color, gaze positions were assessed using an EyeLink 1000 eye-tracker. Results reveal that early fixations are more frequently directed to the novel than to the familiar color, indicating that attention is biased towards the novel color. This result shows that a singleton status of the novel color is not a necessary condition for the biasing of attention. This is consistent with the surprise capture account that novelty (or "schema-discrepancy"), if strong enough, is sufficient to bias attention towards the surprising event.

26.519 Targets previously associated with a unique response attract attention

Rachael E. Gwinn[1](gwinn.32@osu.edu), Andrew B. Leber[1]; [1]Psychology, The Ohio State University

There has been much research aimed at determining how stimuli receive attentional priority. Beyond conventionally defined stimulus-driven and goal-driven contributions, factors such as learned usage of a task set (Leber & Egeth, 2006) and learned value (Anderson & Yantis, 2011) have been shown to affect priority. Here we introduce another factor, response uniqueness, for which targets associated with a unique response attract attention. Experiment 1 began with a training phase: on each trial a single circle, which could be one of six colors, moved across the display. Observers were instructed to produce a speeded go response for five of these colors and no-go for the remaining color. Next, during the test phase, color became task-irrelevant and observers were instructed to attend to shape. The shape on each trial could be a square, diamond, circle, or triangle. Participants now produced a go response to squares and no-go for the other shapes. Test phase results showed participants were faster when the square matched the no-go color from the training phase, suggesting that features previously associated with a unique response are granted greater attentional priority. To then test whether this priority boost was specific to stimuli associated with no-go responses, Experiment 2 reversed the response mapping in the training phase: a no-go response was required for five of the colors while a go response was required for the sixth color. The test phase was identical to that in the first experiment. Here, test phase results now showed that observers responded more rapidly to targets matching the go color from the training phase. This again shows that features pre-

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viously associated with a unique response are granted greater attentional priority. These results contribute to a growing class of factors, based on learning, that are now understood to determine attentional allocation.
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26.520 **Categorical capture of attention** Caroline Barras[1](caroline.barras@unige.ch), Dirk Kerzel[2]; [1]University of Geneva, [2]University of Geneva

We investigated whether distractor elements from the same category as the target disrupt visual search more than distractors from a different category. One group of observers searched for a single target letter in an array of six elements. The distractors were special characters (i.e., #, @). Participants received information about the target (i.e., the letter A) before each block of 46 trials and indicated the colour of the target (green or red) by pressing one of two keys. There were three main conditions. In one third of the trials, only special characters were shown as distractors. In the same category condition, one special character was replaced by a distractor from the same category as the target (i.e., another letter). In the different category condition, one special character was replaced by a distractor from a different category than the target (i.e., a digit). Another group of observers searched for digits with letters as different-category distractors. Results showed that participants were faster to answer with special symbols or distractors from a different category compared to distractors from the same category. The results did not differ substantially between the groups with letter and digit targets. Our findings suggest that the attentional set for a particular target (single letter or single digit) was extended to the target's category. That is, instead of searching for a particular target, observers searched for any member of the target category. Therefore, distractors from the same category attracted attention whereas distractors from a different category did not.

26.521 **Semantic Priming Produces Contingent Attentional Capture by Conceptual Content** Charles Folk[1](charles.folk@villanova.edu), Alex Berenato[1], Brad Wyble[2]; [1]Villanova University, [2]Pennsylvania State University

There is substantial evidence that the capture of spatial attention by salient, irrelevant stimuli is subject to modulation by top-down task set. To accommodate such findings, the theory of Contingent Attention Capture (CAC) proposes that the attention allocation system is "configurable" such that a given stimulus will only capture attention if it is consistent with current top-down "attentional control settings" related to behavioral goals. Most of the previous research on CAC has focused on capture by salient, low level properties, implying that attentional control settings are limited to working memory templates for simple features such as color, orientation, motion, singleton-ness, etc. A recent study, however, found that relatively high-level, categorical content of an image can capture attention if the task requires monitoring for exemplars from that category (Wyble, Folk, & Potter, 2013). This suggests that the activation of categorical representations in semantic memory can also serve as top-down attentional control settings. The present study tested whether these effects are truly the result of semantic memory activation by testing whether images that are semantically related to the task-relevant category also capture attention. Subjects monitored a central RSVP stream for any exemplar (e.g., a ferris wheel) from a pre-specified semantic category (e.g., amusement park rides). Two frames prior to the target image, irrelevant distractor images appeared above and below the stream, one of which could be another exemplar from the relevant category (e.g., bumper cars), an image of a related item (e.g., cotton candy), or an image of an unrelated item (e.g., a hammer). Distractors consisting of exemplar and semantically related images both produced a decrement in target report relative to semantically unrelated distractors, suggesting that the attention allocation system can be configured not only through templates in working memory, but also through the activation and priming of long-term semantic memory representations.

26.522 **Task-irrelevant faces capture attention regardless of perceptual load** Shiori Sato[1](s337.0428@gmail.com), Jun Kawahara[1]; [1]Chukyo University

According to load theory (Lavie, 2010), the perceptual load of cognitive tasks determines the extent of flanker interference such that the ability to identify a central target letter decreases due to interference from peripheral flanker distractors under low perceptual load, whereas no such interference occurs under high perceptual load. It has been unclear whether load theory holds when face distractors are irrelevant to central identification tasks. The present study examined whether human face distractors captured attention under conditions of high perceptual load when the faces were entirely irrelevant to the task. Participants identified a target letter (N or X) in a circular array of five non-target letters. In 10% of the trials, a face distractor simultaneously appeared above or below the search array. In another 10% of the trials, a phase-scrambled control image appeared. No distractor was presented in the remaining trials. Perceptual load was manipulated by varying the type of non-target letters (low load: homogenous non-targets, "o"; high load: heterogeneous non-targets that shared features with the target). Although load theory predicts no or reduced attentional capture, the reaction times for letter identification were delayed in trials with a peripheral face distractor compared with those with a control image. This result suggests that attentional capture by an entirely task-irrelevant distractor occurred regardless of perceptual load. Additional experiments revealed that the capture effect was specific to faces; no capture was obtained with inverted face images or meaningful non-face images (e.g., food). Moreover, Experiment 4 replicated face-specific attentional capture even when the distractor did not share the temporal component of abrupt onset with the search array. These results extend the notion that faces are exceptions to load theory when faces and search items share no common display features.
Acknowledgement: JSPS 23119731

26.523 **The role of biological form in reflexive orienting** Alvin X. Li[1](axl002@ucsd.edu), Maria Florendo[1], Luke E. Miller[1], Ayse P. Saygin[1]; [1]Department of Cognitive Science, University of California San Diego, La Jolla, CA

Introduction: Reflexive orienting is the automatic direction of spatial attention to a location indicated by a cue. Previous research has shown that these effects can be elicited by the eye or body orientation of a social agent. Here, we tested whether the biological-ness of an agent influenced social attentional orienting. Methods: We used a standard attentional orienting paradigm with humanoid agents as cue stimuli. Subjects were asked to perform a speeded target detection task. Cue direction was not predictive of the target's location. Three types of agents were used: a human, and two non-human agents: one with highly humanlike appearance (android), and one with a clearly non-biological appearance (robot). Each trial started with an image of an agent with face and upper body in clear view, followed by another image of the same agent with the head and upper body turned to the right or left (directional cue), or continuing to face forward (neutral cue). A target letter appeared to the right or to the left of the agent after a variable SOA (200, 400, or 60ms). Results: There was a main effect for cue validity; subjects responded faster to valid cues for all agents. There was also a main effect of agent; responses in trials with the robot cue were slower relative to the other agents, whereas the android and human conditions did not differ. There was also a main effect of SOA, but no interaction with agent. Conclusions: Humanoid agents can automatically direct spatial attention regardless of whether they have biological or non-biological status. However, there is a small but consistent RT cost imposed by an agent with non-biological appearance that occurs independently of cue validity. Subsequent studies will use videos to examine potential effects of both motion and appearance on reflexive orienting.
Acknowledgement: NSF CAREER BCS-1151805

26.524 **Attentional capture by signals of threat** Jan Theeuwes[1](J.Theeuwes@psy.vu.nl), Lisette J. Schmidt[1], Artem V. Belopolsky[1]; [1]VU University Amsterdam

The expectation of punishment and reward is known to be the driving force behind adaptive behavior and learning as it fosters motivational control. A lot is known about the motivational effect of punishment and reward (e.g. Engelman & Pessoa, 2007). Recently several studies have indicated the importance of reward in guiding attention, as stimuli that are associated with reward automatically capture attention, even in the absence of an explicit reward (Anderson et al., 2011; Hickey et al, 2010; Theeuwes & Belopolsky, 2012). Not much is known about the effect of punishment on attentional processing. The present study investigated whether a neutral stimulus which became associated with fear, captured attention in visual search. Using a fear conditioning procedure, one stimulus was repeatedly combined with an electrical shock (CS+), whereas another stimulus with identical physical features was never combined with a shock (CS-). Following conditioning, participants had to search for a target while on some trials, either an irrelevant CS+ or CS- stimulus was present. The results show that the presence of an irrelevant distractor with a learned fear association slowed search more than a distractor without fear association The present study shows that the presence of irrelevant threatening stimuli interferes with the completion of explicit task requirements. Even though all stimuli were initially neutral and did not differ in their physical salience, fear conditioning made one stimulus more salient than the other causing a magnification of attentional capture. Similar to the earlier studies showing an effect of reward on attention, the current results indi-

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cates that learned fear associations have the ability to grab our attention even if we try to avoid them. It is consistent with previous studies showing that stimuli with emotional value are prioritized in visual selection.

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26.525 **The Role of Rapid Disengagement in Overcoming Attentional Capture** Tashina Graves[1](tgrave15@jhu.edu), Hrag Pailian[1], Howard Egeth[1]; [1]Department of Psychological and Brain Sciences, Johns Hopkins University

Can top-down control be used to overcome cross-dimensional attentional capture by a salient singleton? Here, we test an alternative to the hypothesis that training people to search for a specific target (feature search) eliminates capture by an irrelevant singleton. Specifically, we investigate whether feature-trained individuals are simply able to more efficiently disengage from an irrelevant singleton and reorient towards a target, compared to a group previously trained to look for a unique item (singleton search). In Experiment 1, we replicated the feature and singleton training methods used by Leber and Egeth (2006). In the test displays of our transfer session, participants were presented with 5 shapes (1 circle, 4 squares), enclosing differently oriented lines. Participants were instructed to identify the orientation of the line within the circle. This display was presented for 30, 60, 90, or 120 ms, and the lines appearing within the shapes either disappeared or were replaced by masks. Response accuracy was measured. On a subset of trials, one of the non-targets was a color-singleton distractor. We expected that at short display durations, feature- and singleton-trained individuals would perform less accurately when the distractor was present, due to insufficient time to disengage from the distractor and reorient towards the target. We found a difference in accuracy at 90 ms between distractor present and absent trials for both groups when a mask was presented. To determine whether this difference resulted from a lack of rapid disengagement and reorienting (and not a filtering cost), we conducted a similar investigation (Experiment 2) with feature-trained participants, in which the orientation of the line within the distractor matched the identity of the line appearing within the target on half of all trials. We observed a congruency effect at 60 ms, suggesting that feature-trained participants processed the information within the singleton distractor.

26.526 **An Inability to Set Independent Attentional Control Settings by Hemisphere** Mark W. Becker[1](becker54@msu.edu), Susan M. Ravizza[1], Chad Peltier[1]; [1]Department of Psychology, College of Social Science, Michigan State University

Recent evidence suggests that people can simultaneously activate attentional control settings (ACSs) for two distinct colors.However, it is unclear whether both ACSs must operate globally across the visual field or whether each can be constrained to a particular spatial location. Using two different paradigms we investigated participants' ability to apply independent color ACSs to distinct regions of space. In both experiments, participants were told to identify red letters in one hemifield, and green letters in the opposite hemifield. Additionally, some trials used a "relevant distractor" - a letter that matched the opposite side's target color. In Experiment 1, four letters appeared simultaneously in each hemifield for a brief period of time and were masked. Relevant distractors increased the error rate and resulted in a greater number of distractor intrusions than irrelevant distractors. Similar results were observed in Experiment 2 in which red and green targets were presented in two rapid serial visual presentation streams. Relevant distractors were found to produce an attentional blink similar to an actual target and increased the false alarm rate. The results of both experiments suggest that letters matching either ACS were selected by attention and were processed as if they were targets, providing strong evidence that both ACSs were applied globally, rather than being constrained to a particular location.

26.527 **Capturing Attention: Fixation Not Required** Joanna Lewis[1](joanna.lewis@knights.ucf.edu), Mark Neider[1]; [1]Department of Psychology, University of Central Florida

Looming motion has previously been shown to capture attention in a visual search task (Lin, Franconeri, & Enns, 2008); when targets loom toward an observer, search times are faster compared to when targets are static or distractors are looming. Although this finding has been replicated, there does appear to be an interesting caveat. More specifically, costs associated with looming distractors only seem to occur when object motion is smooth (compared to apparent) and that capture is rarely associated with an overt eye movement (Lewis & Neider, 2013). To determine whether the latter finding reflects covert attentional shifts or was a byproduct of peripherally discriminable search items, we ran two experiments in which we increased the difficulty of discriminating an oval target from distractor spheres, relative to our previous studies. Within each trial, a target (8% deformation from spheroid) or distractor could loom, or all items were static (control condition). In Experiment 1 motion was apparent and in Experiment 2 motion was smooth. Objects were presented centrally (5.5° from center) or peripherally (10.5° from center). In both experiments, there was an RT benefit for looming targets (~307 ms and ~230 ms for Experiments 1 and 2, respectively). Replicating our previous findings, looming distractors only induced an RT cost when motion was smooth (~96 ms). With harder targets, participants made a higher proportion of target fixations compared to our previous studies with easier targets (~85%). Participants fixated on looming distractors more when located centrally than in the periphery (~68% and 48%, respectively). When there was a looming distractor, participants fixated on more objects per trial compared to control trials. Overall, these results indicate that looming targets capture overt attentional shifts, but looming distractors do not always result in fixation capture.

26.528 **Correction of distractor-bound saccades depends on available evidence of error.** Nicholas DiQuattro[1,2](ndiquattro@ucdavis.edu), Joy Geng[1,2]; [1]Center for Mind & Brain, University of California, Davis, [2]Department of Psychology, University of California, Davis

Attentional capture is a well-studied phenomenon where task-irrelevant stimuli are erroneously selected for processing. While stimulus features that cause attentional capture have been extensively documented, the ability of the attentional system to attenuate the effects of capture remains largely unknown. In Experiment 1 (N=24), we identified three saccade metrics that were adjusted to limit processing of the irrelevant distractor. We recorded eye-movements during a visual search task in which a target was simultaneously presented with a distractor that was the same color as the target (similar distractor) or was a different color (dissimilar distractor). Applying a machine-learning algorithm (support vector machines) to within-subjects data, we found that first-saccades to dissimilar distractors had shorter saccade latencies, saccade amplitudes, and distractor fixation durations. This suggested that corrective mechanisms operate at multiple levels of processing, even as an erroneous saccade is being executed. In Experiment 2, we manipulated the distractor-target onset asynchrony (SOA; N=24) and found that the degree of saccade correction scaled with SOA. In Experiment 3, we varied target-distractor color similarity (N=24) and again found a scaling of correction, now based on feature similarity. Together these results demonstrated that the ability to initiate corrective mechanisms to limit distractor processing depended on the strength of evidence that the planned saccade was erroneous.

26.529 **Dual processes of oculomotor capture by abrupt onset: Rapid involuntary capture and sluggish voluntary prioritization** Yue Qi[1](qiy@psych.ac.cn), Feng Du [1], Xingshan Li[1], Kan Zhang[1]; [1]Key Laboratory of Behavioral Science, Institute of Psychology, Chinese Academy of Sciences

The present study showed that there are two distinctive processes underlying oculomotor capture by abrupt onsets. When a visual mask between the cue and the target eliminates the unique luminance transient of an onset, the onset still attracts attention in a top-down fashion. This memory-based prioritization of onset is voluntarily controlled by the knowledge of target location. But when there is no visual mask between the cue and the target, the onset captures attention mainly in a bottom-up manner. This transient-driven capture of onset is involuntary because it occurs even when the onset is completely irrelevant to the target location. In addition, the present study demonstrated distinctive temporal characteristics for these two processes. The involuntary capture driven by luminance transients is rapid and brief, whereas the memory-based voluntary prioritization of onset is more sluggish and long-lived.

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26.530 **The Effect of Simulated Red Light Running Camera Flashes on Attention and Oculomotor Control** Walter Boot[1](boot@psy.fsu.edu), Robert Sall[1], Timothy Wright[1]; [1]Department of Psychology, Florida State University

We explored whether Red Light Running Camera (RLRC) flashes can pull attention away from safety-relevant changes in simulated driving scenes using Inhibition of Return (IOR) and eye movement errors as measures of attention capture. Participants were asked to respond to the onset of brake lamps of a vehicle within a driving scene with a manual response (Experiment 1) or eye movement (Experiments 2 & 3). Manual and saccadic response times revealed strong IOR effects suggesting that, consistent with anecdotal reports, RLRC flashes can capture attention. At first participants were faster when the RLRC flash occurred on the same side of the display as the brake

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lamp event, but after approximately 300ms facilitation transitioned to inhibition. Furthermore, participants made erroneous eye movements to the flash rather than the brake lamp event when the flash was relatively infrequent (occurring on approximately 10% of trials). Additional experiments will be presented that explore how spatial predictability of the relevant roadway event can modulate the degree to which RLRC flashes can capture attention. This initial evidence for capture by RLRC flashes suggests that more research is necessary to examine how RLRC flash distraction might impact driving performance, and whether this distraction might partially explain the increase in certain types of crashes at intersections with RLRCs.

26.531 **Functional Fixedness: The Functional Significance of Delayed Attentional Disengagement Based on Attention Sets** Timothy Wright[1](timwright@psy.fsu.edu), Walter Boot[1]; [1]Department of Psychology, College of Arts and Sciences, Florida State University

Numerous studies have found that attention dwells on an irrelevant item longer when the features of this item match an observer's attention set (Blakely, Wright, Boot, & Brockmole, 2011; Boot & Brockmole, 2010; Wright, Boot, & Jones, submitted). This delayed disengagement effect has been proposed to automatically prolong the processing of task-relevant information to discourage cases in which fixations are too brief to allow the target of search to be recognized before attention moves on. While previous studies have robustly demonstrated that attentional disengagement is automatically delayed when the currently fixated (but irrelevant) item shares properties of the search target, so far there has been no evidence that increased fixation duration results in a greater depth of processing of the fixated item. To explore this component of attentional disengagement effects a flanker task was incorporated into the oculomotor disengagement paradigm. Observers searched for a green or blue target in the periphery and indicated the identity of the target letter within it after saccading away from an irrelevant item that was either consistent or inconsistent in color with the target. The irrelevant item within fixation also contained a flanker letter that was either consistent or inconsistent with the identity of the letter within the search target. Results suggest that an observer's attention set not only determines how long attention dwells at a location (replication of previous studies) but also how deeply information is processed at that location: the identity of the item within the initially fixated item only produced a flanker effect when this item was the same color as the search target. In conclusion, delays in disengagement do appear to be functionally significant. Future research will examine if this increase in processing influences memory for items consistent with the observer's attention set as well.

Attention: Endogenous and exogenous

Saturday, May 17, 2:45 - 6:45 pm
Poster Session, Pavilion

26.532 **Spatial attention in the visual field: a unitary system?** Yan Bao[1](baoyan@pku.edu.cn); [1]Department of Psychology and Key Laboratory of Machine Perception (MoE), Peking University

Although early neurobiological and psychophysical evidence indicates some inhomogeneities of the human visual field such as different sensitivities measured by light-difference thresholds and different saccadic programming modes for perifoveal and peripheral stimuli, attention control in the visual field is traditionally believed to be homogenous. Using spatial cueing paradigms new evidence has been accumulated, pointing towards a functional subdivision of attention control in the visual field. Specifically, the periphery is significantly different from fovea and perifoveal regions of the visual field. An overview of behavioral studies measuring both exogenous and endogenous cueing effects as well as imaging studies measuring inhibition of return effects using ERP, fMRI and MEG technologies is provided to systematically examine these new observations. Different attention systems rather than one unitary system responsible for the attention control in different areas of the visual field are proposed. References Bao, Y., Lei, Q., Fang, Y., Tong, Y., Schill, K., Pöppel, E., & Strasburger, H. (2013). Inhibition of Return in the Visual Field: the Eccentricity Effect is Independent of Cortical Magnification. Experimental Psychology. 60, 425-431. Bao, Y., & Pöppel, E. (2007). Two spatially separated attention systems in the visual field: evidence from inhibition of return. Cognitive Processing, 8: 37-44. Bao, Y., Sander, T., Trahms, L., Pöppel, E., Lei, Q. and Zhou, B. (2011). The eccentricity effect of inhibition of return is resistant to practice. Neuroscience Letters, 500: 47-51. Bao, Y., Wang, Z., Liang, W., Wang, Y., Pöppel, E., & Li, H. (2013) Inhibition of Return at Different Eccentricities in the Visual Field Share the Same Temporal Window. Neuroscience Letters, 534, 7-11. Lei, Q., Bao, Y., Wang, B., & Gutyrchik, E. (2012). fMRI Correlates of Inhibition of Return in Perifoveal and Peripheral Visual field. Cognitive Processing, 13(Suppl.), 223-227. Acknowledgement The studies were supported by the NSFC (No. 30670703, No.91120004, and No. 31371018).

26.533 **Balancing internal and external attention: mind-wandering variability predicts error awareness** Micah Allen[1,2](mga.neuro@gmail.com), Jonathan Smallwood[3], Geraint Rees[1,2]; [1]Institute of Cognitive Neuroscience, London WC1N 3AR, UK, [2]Wellcome Trust Centre for Neuroimaging, UCL Institute of Neurology, London WC1N3BG, UK, [3]Department of Psychology, University of York, York, UK

Spontaneous, endogenously driven fluctuations in attention are common occurrences, impacting both cognition and well-being. Such fluctuations, known as 'mind-wandering', are often treated as executive failures and recruit the default mode network (DMN). However, recent evidence suggests that task-unrelated thoughts (TUTS) can also facilitate memory, creativity, and meta-cognition. To clarify the costs and benefits of mind-wandering, we investigated TUTs during the error-awareness fMRI task (EAT). 42 participants (27 females) completed the EAT during fMRI scanning. The EAT is a visuomotor response inhibition task with color-word "Go" (e.g. the word red colored green) and "Stop" targets (the word red colored red). Participant's TUT intensity (1-7) was assessed at pseudo-random intervals. For each participant, mean stop accuracy (SA), error-awareness (EA), TUT intensity (TUTMean), and TUT variability (TUTSD) were calculated. Blood-oxygenation level dependent responses to stop accuracy, aware > unaware errors, and the parametric correlation with TUT intensity were analyzed. Multiple regression analyses with TUTmean and TUTSD as predictors for both SA and EA revealed a strong positive relationship between TUTmean and SA and between EA and TUTSD. Our fMRI analysis found a pattern of activations in the central executive network, coupled with deactivations in visual, medial prefrontal, and posterior parietal cortex. Aware > unaware errors recruited activations in anterior insula and the inferior parietal cortex. Interestingly, TUT-intensity recruited a more rostral region of medial prefrontal cortex to that deactivated during Stop trials. We replicated the link between TUTs and cognitive control, demonstrating that increases in mind-wandering relate to greater executive failure. However, we also found that error-awareness recruited DMN regions and that participants with a higher capacity for monitoring displayed greater TUT fluctuation. Fluctuating between internal and external attention may thus facilitate metacognition. Future research may determine if clinical disruption of error awareness is related to reduced TUT variability.

26.534 **Expectation and IOR: Effects on eye movements and ESP** Alex Gough[1](goughaw@mcmaster.ca), Jim Zhou[1], Zachary Livshin[1], Bruce Milliken[1], David Shore[1]; [1]Psychology, Neuroscience & Behaviour, McMaster University

There is renewed interest in the idea that expectation contributes to the inhibition of return (IOR) effect in spatial orienting. Spalek (2007) asked participants to report where they thought a target was programmed to appear (although a target never actually appeared) following presentation of an abrupt-onset peripheral cue. Participants reported "expecting" a target to appear opposite the cue with greater-than-chance likelihood, and to appear at the cued location with lower-than-chance likelihood. However, using a different task in which participants guessed in which of four locations a target was hidden, Danziger and Rafal (2009) reported the opposite result: greater-than-chance selection of the cued location. The present study aimed to determine why opposite patterns of results occurred in these two studies. In Experiment 1, a procedure similar to Spalek (2007) was used, and similar results were observed. In Experiment 2, participants shifted their eyes to the location where they expected the target to appear following an abrupt-onset cue, triggering the appearance of the target. In contrast, to Experiment 1, participants made "expectation" eye movements to the cued location with greater-than-chance likelihood. A potential key difference between Experiments 1 and 2 is that expectations could be confirmed or disconfirmed by target presentation in Experiment 2 but not in Experiment 1. The procedure in Experiment 3 replicated Experiment 1 but with targets presented following each response. Indeed, the results of Experiment 3 resembled those of Experiment 2. The results of these experiments demonstrate that there is unlikely to be one foolproof way to measure "expectation", and that behaviours that appear to measure expectation are sensitive to task-specific factors that can lead to either of two conclusions; that a pattern of measured expectation is consistent with the behavioural IOR effect, or that a pattern of measured expectation is completely counter the behavioural IOR effect.

Acknowledgement: NSERC

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26.535 **Inhibition of return affects contrast sensitivity** Ayelet Sapir[1](a.sapir@bangor.ac.uk); [1]School of Psychology, Bangor University

Inhibition of return (IOR), a slow response to targets appearing at recently attended locations, is believed to play an important role in guiding behaviour. Attentional capture and automatic orienting of attention affects early perceptual processes such as contrast sensitivity and spatial resolution, suggesting that shifting attention to a location enhances perception of targets therein. Whether the effects of IOR simply impede orienting to specific locations or also affect early perceptual processes, such as contrast sensitivity, has not been clarified yet. We found that contrast sensitivity was increased in both a detection and a discrimination task when the target appeared, shortly following an exogenous cue, at the cued location. However, the sensitivity was diminished when the target appeared at the cued location at delays where IOR is known to take place. These results clearly demonstrate that IOR affects early perceptual processes, and that both attentional capture and IOR modulate contrast sensitivity.

26.536 **The relationship between contrast detection and saccadic reaction times with attention.** Madhumitha Mahadevan[1](Madhumitha.opt@gmail.com), Harold Bedell[1], Scott Stevenson[1]; [1]University of Houston, College of Optometry

Visual spatial attention can increase contrast sensitivity and decrease saccadic or manual reaction times (RTs) in attended compared to unattended locations. As stimulus contrast also influences saccadic RT, we asked whether the effect of attention on saccadic RT can be accounted for by the change in contrast sensitivity. We used a dual task paradigm that recorded saccadic RTs and psychophysical responses to targets of various contrast. On each trial, subjects were presented with a central fixation stimulus, which also carried an endogenous cue (an arrow) to the target's radial direction but not its eccentricity. Across trials, the cue was 75% valid, 12.5 % invalid and 12.5 % neutral (no arrow). Circular gratings m-scaled for eccentricity were flashed for 8 ms in one of 8 radial directions around fixation, at either 3 or 6 deg eccentricity, with one of 9 contrasts. The subjects' tasks were to (1) saccade to the location where the target flashed and (2) respond via button press if the target flashed at the nearer (3 deg) or the farther (6 deg) eccentricity. Saccadic RTs and psychophysical responses to targets at the different contrast levels were analyzed to assess the effects of cueing. Valid cueing produced a factor of 1.2 increase in contrast sensitivity, relative to invalid-cue trials. Valid cueing also reduced saccadic RTs for contrast levels at and above the detection threshold. However, the effect of cueing on saccadic RT is accounted for only partly by the increase in psychophysical contrast sensitivity. A comparison of RT vs. contrast for valid and invalid cueing shows a combined effect: a shift consistent with the observed change in contrast sensitivity, and an overall change in latency of roughly 20 msec. Attention appears to influence saccadic RTs in more than one way.

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26.537 **The onset of background dynamic noise degrades preview benefit in inefficient visual search** Takayuki Osugi[1](tosugi@fechner.c.u-tokyo.ac.jp), Ikuya Murakami[1]; [1]Department of Psychology, The University of Tokyo

When some distractors (old items) appear before others (new items) in an inefficient visual search task, observers exclude the old items from the search (preview benefit), possibly because their locations are deprioritized relative to the locations of new items. Previous studies have shown that transient motion at the old item's location disrupts preview benefit. What type of change degrades the preview benefit? We examined whether participants were able to ignore a task-irrelevant change in the scene, namely the motion initiation/cessation of dynamic noise in the background, while they were doing a preview search task in which the old items were presented for 1 s before the new items were added. All these items were superimposed on static or dynamic random luminance noise. The target to be searched for could be present only within the new items. Participants were requested to make speeded reaction to the target among distractors in several set sizes. Preview benefit was assessed by testing whether the search function under the preview condition explained above was significantly shallower than that under the baseline condition, under which all items appeared simultaneously. The results indicated that when the motion initiation of the dynamic noise was synchronized with the onset of the new items, this task-irrelevant event in the background degraded the preview benefit on search efficiency. In contrast, when the noise continually moved throughout each trial or when the motion cessation of the noise was synchronized with the onset of the new items, the preview benefit remained. Therefore, synchronizing the onset of the motion display with the onset of the new items was critical for the degradation of the preview benefit, suggesting that the onset of task-irrelevant background motion disrupts either inhibitory marking of the old items or attentional allocation to the new items.

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26.538 **Speed and accuracy of decoding cue meaning are not related to the extent of a cueing effect: A comparison among predictive arrow, color and number cues** Bettina Olk[1](b.olk@jacobs-university.de), A. Raisa Petca[2], Adalbert F. X. Wilhelm[1]; [1]School of Humanities and Social Sciences, Jacobs University Bremen, [2]Centre for Intervention Research in Schools, Ohio University

Predictive arrow cues, which have traditionally been used to measure effects of voluntary attention, elicit a combination of involuntary and voluntary orienting. To measure effects of voluntary orienting in isolation, recent research has employed predictive number and color cues. The observed effects of the latter are smaller than those obtained with predictive arrows. We assessed whether this difference is related to the ease of decoding cue meaning, following the rationale that it may be easier to process direction information instructed by symbols such as arrows than by arbitrary numbers or colors and that this advantage of arrows may influence cueing effects. The same participants completed two separate conditions/tasks. They judged the direction indicated by a stimulus (left or right arrow, numbers 1 or 2, numbers 3 or 9, red or green) and detected a target following a predictive cue (arrow, number, color). They were significantly faster and more accurate at judging arrows than all other stimuli and exhibited a significantly larger cueing effect with arrows than all other cues. Critically, differences in speed and accuracy of judging stimulus direction were not correlated with the differences in cueing effects. This lack of a relationship was supported by Bayesian analyses, with all Bayes factors indicating substantial evidence in favor of the null hypothesis for no correlation. A lack of a correlation was supported by the observation that participants were better at judging direction of colors and numbers 1/2 compared to numbers 3/9, while the cueing effects in those three conditions were the same. Smaller cueing effects produced by predictive numbers and colors than arrows may rather be explained by the type of orienting that is engaged (predictive numbers and colors elicit voluntary orienting; predictive arrows measure a combination of voluntary and involuntary orienting) than by the ease of decoding cue meaning.

26.539 **Attention improves precision while short-term memory load increases guessing** Christie Rose Marie Haskell[1](crmhaske@uwaterloo.ca), Britt Anderson[1]; [1]University of Waterloo

In an orientation judgement task Liu and Becker (2013) demonstrated that working memory load affected participants' guesses, but not response precision. As attention has previously been shown to affect the precision of orientation judgements (Anderson & Druker, 2013), we were interested in investigating the effect of attention and visual short-term memory together in the same task, and with varying memory demands and cue reliabilities. Experimentally, two gabors at different orientations briefly appeared. Participants rotated a centrally presented response gabor to match one of the indicated target gabors. Attention was manipulated by a brief luminance cue and memory by presenting the two possible targets simultaneously or sequentially. Increased memory load increased the proportion of trials on which participants guessed. When attentional cues were informative, the precision of responses improved. When the cue was not informative, participants made fewer guesses on valid trials compared to invalid trials. Precision was unaffected by a non-informative spatial cue. Our results provide evidence that under conditions of reduced target uncertainty, attention improves precision because resources do not need to be divided across two stimuli, whereas when two gabors are equally probable targets, attention improves the likelihood that the stimuli will be encoded into memory. For both informative and non-informative cues, the cueing effect was larger on simultaneous compared to sequential trials, providing evidence that attention also serves to reduce competition from irrelevant stimuli.

26.540 **Statistical Learning Modulates the Flexible Control of Spatial Attention** Anthony W. Sali[1](asali1@jhu.edu), Brian A. Anderson[1], Steven Yantis[1]; [1]Department of Psychological and Brain Sciences, Johns Hopkins University

Fluctuations in preparatory cognitive control have important behavioral consequences for goal-directed attentional selection. In particular, the speed with which individuals update selections varies according to preparatory control settings. We tested whether the statistical properties of an environment persistently modulated preparatory states of attentional control. In each of three experiments, participants held and shifted attention between two rapid serial visual presentation streams of alphanumeric characters in response to visual cues. Behavioral response times (RT) to target stimuli immediately following a cue provided an index of attentional flexibility. In Experiment 1, we varied the frequency of shift and hold cues across time during a training phase. Shift costs were smaller at intervals when shift cues were frequent, suggesting that control settings were modulated according to the statistical structure. In a subsequent test phase, we presented both cue types with equal frequencies across time. We found minimal transfer of control states after this switch in cue probabilities. In Experiment 2, we manipulated the frequency of shift and hold cues in separate blocks of stimuli. In further support of statistical learning, shift costs varied based on cue probabilities across contexts and this RT difference persisted throughout a subsequent test phase in which both cue types were equally likely. Lastly, in Experiment 3, we paired the temporal and contextual manipulations of the first two experiments. Cue probabilities varied across time as in Experiment 1, but critically, stimulus color predicted which of two opposing probability structures was in effect on a trial-by-trial basis. Unlike the first two experiments, we found no evidence of learning-based modulations of cognitive control for this more complex statistical structure. Taken together, our findings provide evidence that the statistical properties of an environment play an important role in guiding the flexible deployment of attention.

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Attention: Temporal

Saturday, May 17, 2:45 - 6:45 pm
Poster Session, Pavilion

26.541 Alpha-pulse sampling in attention revealed in saccade latency behavior

Kun Song[1](zgndsongkun@126.com), Lin Chen[1], Huan Luo[1]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Biophysics, Chinese Academy of Sciences, Beijing

Neuronal oscillations are ubiquitous in the brain and contribute to perception and attention. However, most associated evidence derives from post-hoc correlations between brain dynamics and behavior. Our previous work (Luo et al., VSS2013), by measuring response time (RT) in a high resolved manner, demonstrates compelling dynamic oscillatory pattern (theta-mediated alpha pulses) directly in behavioral measurement in a precuing task. We speculate that those behavioral oscillations may reflect underlying neuronal oscillatory mechanism in multi-object attention. Here, we examined whether the spectro-temporal dynamics could also be observed when using eye movement response instead of motor response. After a peripheral uninformative cue shown at one of the two peripheral boxes, a target was presented in the cued or uncued box at varying SOAs (0.1~1 s in steps of 20 ms), and subjects were asked to make saccade to the target as fast as possible, and to not make saccades in catch trials when target was absent. Eye movements were recorded using Eyelink1000 system, and the saccade latency was recorded for each condition (Valid and Invalid) as a function of cue-to-target SOA. Our preliminary results (N=7) replicate typical IOR effects in low-pass filtered saccade latency time courses. Most importantly, the behavioral measurement, indexed by saccade latency here, shows a similar trend of dynamic oscillatory pattern as observed previously in RTs. Specifically, an uninformative peripheral cue elicits rhythmic alpha pulses (8-20 Hz) in saccade latency time courses, and the elicited alpha pulses for cued and uncued conditions are in a certain temporal relationship. In conclusion, the present eye movement findings, combined with our previous RT results, suggest that behavioral performances actually consist of rich dynamic and may reflect underlying neuronal oscillatory substrates. Our data also suggest the critical role of coordinated alpha-band pulse in sampling multiple objects.

26.542 The locus coeruleus-noradrenaline system facilitates attentional processing of action-triggered visual stimuli

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Previous studies have demonstrated that attentional processing of visual stimuli is facilitated when stimulus onset is triggered by a voluntary action. However, little is known about the neurobiological mechanisms underlying this facilitation effect. Here we showed that the locus coeruleus-noradrenaline (LC-NA) system activating before the voluntary action is involved in the facilitation of attentional processing. We focused on pupil dilation that reflects the function of LC-NA system. We measured participant's pupil size when the participant performed a rapid serial visual presentation task at the rate of 20 items/s. Under the voluntary conditions, after participant's key press, the items in the task were switched from numerals of nontargets to letters of targets with temporal delays: 0-50, 100-150, 200-250, 300-350, 400-450, 600-650, and 800-850 ms. The switch occurred automatically without the key press under the control condition. These conditions were blocked. Participants were asked to report the first four successive letters as targets. The second target was reported significantly more under the 600-650 ms delay condition than under the control condition. This indicates the facilitation of attentional processing of the second target triggered by the action. The facilitation effect is tightly linked with the activation of the LC-NA system: pupil size from the stimulus onset to the key press increased in the 600-650 ms delay condition than in the automatic condition. This pupil dilation occurred only at the end of the condition block, suggesting that the LC-NA system activates after participants learn the delay between the voluntary action and the onset of targets. We conclude that the LC-NA system plays an important role in the facilitation of transient attention for visual stimuli triggered by the voluntary action.

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26.543 Unattended feature interference during a dynamic sequence task

Sarah C. Tyler[1](sctyler@uci.edu), Charles Chubb[1], Emily D. Grossman[1]; [1]Department of Cognitive Sciences, Center for Cognitive Neuroscience, UCI, Irvine California 92697

Introduction. Success in filtering irrelevant information depends on the relative salience of attended and unattended features, and the attentive demands of the task (Lavie, 2004). In difficult tasks, high salience features are robust against the interfering potential of irrelevant distractors, even when the distractors are also highly salient (Lu and Han, 2009.). When targeted features have low salience, sensitivity is more susceptible to the influence of distractors. In this experiment, we measure if attention to features of a dynamic sequence (either relative timing and contrast) is modulated by the second unattended feature. Methods. Subjects viewed a pair of discs (4 degrees eccentric) flickering aperiodically (with an average flicker rate of 3-15Hz) between black and white for 1000 ms. By using aperiodic sequences, we were able to manipulate the color contrast and phase synchrony relationships independently (between completely uncorrelated and correlated, in 25% increments). Subjects were asked to attend to and judge the simultaneity of the discs based either on 1) color contrast, or 2) onset/offset timing (phase). Results. Subjects' rating of the perceived simultaneity of color contrast tracked closely with the veridical color synchrony between the discs (e.g. when the discs are 75% in sync, subjects judge the discs to be similar 75% of the time). This was true regardless of flicker rate (6-15Hz) and phase synchrony. Ratings of temporal phase (relative timing of onsets and offsets) were not correlated with the actual phase relationships of the disks, regardless of flicker rate (2.5-9 Hz). Conclusions. Subjects can successfully attend to the contrast of the flickering discs, without interference from the relative timing and flicker rate. Because contrast is a highly salient feature, subjects may be unable to disengage attention from the color patterns of the discs in order to determine temporal phase relationship.

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26.544 Electrophysiological evidence of misselection during the attentional blink

Benoit Brisson[1](benoit.brisson@uqtr.ca), Marie-Ève Bourassa[1], François Vachon[2]; [1]Université du Québec à Trois-Rivières (Psychologie), [2]Université Laval (École de psychologie)

The attentional blink (AB) refers to the impairment in accurate report of a second target (T2) when presented shortly after a first target (T1) in a rapid serial visual presentation (RSVP) of distractors. ERP studies have shown that the P3 to T2 is attenuated during the AB. This attenuation has often been taken as evidence for the capacity-based models, which assume that only one target can be consolidated in short-term memory at one time. However, the attenuation of the P3 to T2 could also be the result of misselection errors, in which the following item (T2+1) is consolidation instead of T2. The goal of the present study was to investigate the misselection hypothesis by measuring the P3 to T2 and to T2+1. Targets were red uppercase letters in a distractor stream of black uppercase letters. T2 could be presented at Lag 3 (during the AB) or at Lag 7 (outside the AB). Participants had to identify whether T1 was before or after M in the alphabet and whether T2 was an E or not. In order to compute the frequency-related P3 to T2, T2 was an E in 25% of trials and a non-E in 75% of trials. The T2+1 distractor was also an E in 25% of trials and a non-E in 75%, which enabled us to compute a frequency-related P3 to T2+1. An attenuation of the P3 to T2 was observed during the AB, replicating previous results. Interest-

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ingly, an increase in the amplitude of the P3 to T2+1 was also observed during the AB. Moreover, the P3 to T2+1 was present only in trials were T2 was incorrectly reported, whereas the P3 to T2 was present only when T2 was correctly reported. These results support the misselection hypothesis.

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26.545 **Reconstructing temporal organization of visual attention reduces attentional blink** Peijun Yuan[1,2](jane.ypj@163.com), Ying Wang[1], Yi Jiang[1]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Psychology, Chinese Academy of Sciences, Beijing, China, [2]University of Chinese Academy of Sciences, Beijing, China

In this ever-changing world, large portions of the information we receive and attend to are operating in time with a rhythmic pattern (e.g., music and biological motion). However, little is known about whether such rhythmic information can influence the deployment of temporal attention. Here we provide evidence that entrainment to metrical tones played in the background can reconstruct the temporal deployment of visual attention in an organized manner. We took advantage of the attentional blink (AB) phenomenon, which is characterized by an impairment of visual attention in detecting a second target temporally proximate to the first one in a rapid sequence of visual stimuli. We found that the AB effect was significantly reduced when the two targets appeared in adjacent, rather than in the same, temporal structures defined by the periodic alternation of high- and low-pitch tones, suggesting that visual selective attention can be recomposed by irrelevant rhythmic information even from an unattended sensory modality. Consistent with this temporal organization assumption, disrupting the rhythmic auditory structures completely abolished the effect. Rather than accentuating the salience of individual events at specific temporal positions, our findings indicate that the AB effect can be modulated by the dynamic organization of sensory inputs. More importantly, we highlight the role of neural entrainment in reconstructing the temporal organization of attention.

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26.546 **The Exact Timecourse of Attention: The Mutations Paradigm** Ricardo Max[1](ricardom@post.tau.ac.il), Yehoshua Tsal[1]; [1]Department of Psychology, Tel Aviv University

Theories of attention rely on specific assumptions regarding the order of events mediating attentional modulation of perceptual processing. Yet, behavioral investigations of the timecourse of attentional operation remain largely absent. The mutations paradigm comprises a modified flanker task that assesses the time window of distractors' processing, with high temporal resolution. We report main patterns consistently observed across five experiments. A central target was flanked by two identical distractors, which were either disruptive or neutral. While the target remained unchanged, distractors mutated once per trial, at a random time. There were three trial types; disruptive distractors that mutated to neutral ones, vice-versa, or neutral distractors that mutated to different neutral distractors (control). These manipulations revealed the time window during which disruptive distractors must appear in order to impair performance. Results revealed four main patterns: (1) Presentations of disruptive distractors within the initial 8 ms were sufficient to delay responses (distractor identification). (2) Disruptive distractors presented later than ~50 ms became effectively ignored (distractor suppression). (3) Enhancements of inter-target discriminability from low (targets M and N) to high (M and O) produced faster RTs, earlier distractor identification, earlier distractor suppression and less distractor interference. These patterns support dual-process claims that initially all stimuli are identified and then distractors are inhibited (e.g., Driver & Tipper, 1989) and are inconsistent with (a) early-selection claims that stimuli identification occurs only after attentional mechanisms modulate perception; (b) late-selection claims that attentional modulation is post-perceptual; (c) load theory claims that distractors are processed only under low load conditions, by surplus resources, after target processing (Lavie, 1995). (4) Priming of recurrent targets' features produced earlier distractor suppression, later distractor identification and less distractor interference, as predicted by contingent capture claims (Folk, Remington, & Johnston, 1992). We suggest that the temporal relationship between bottom-up identification and top-down suppression modulates selection efficiency.

26.547 **Rhythmic motion regulates spontaneous perceptual alternation** Ying Wang[1](wangying@psych.ac.cn), Xue Zhang[1,2], Qian Xu[1,2], Yi Jiang[1]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Psychology, Chinese Academy of Sciences, [2]University of Chinese Academy of Sciences

During prolonged viewing of ambiguous visual patterns, perception fluctuates spontaneously between two competing interpretations. Such phenomenon of perceptual alternation is valuable for investigating the temporal dynamics of visual processing, which presumably reflects the oscillatory nature of neural activities. Here we demonstrate that despite the inevitable fluctuation, spontaneous perceptual alternation can be regulated by external rhythms in the form of cyclic motion, resulting in a linear covariation between the cycle repetitions and the perceptual alternations. This effect was observed for biological motion as well as for artificial motions that simulated the kinematic properties of biological motion or had a regular acceleration-defined cycle, but is not evident when periodicity was imposed on the motion signals through adding irregular acceleration or regular color or luminance information. Moreover, the distribution of perceptual durations can be described by a gamma function with the shape varied with the rhythmic motion cycle rather than other temporal properties of the motion stimuli. These results suggest that the intrinsic dynamic characteristics of visual processing can be regulated by external rhythmic motion information, and argue for a potential role of neural entrainment in triggering rhythmic visual processes.

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26.548 **Onset target escapes the background perceptual grouping** Chia-huei Tseng[1](CH_Tseng@alumni.uci.edu), Hiu Mei Chow[1,2]; [1]Department of Psychology, The University of Hong Kong, [2]Department of Psychology, The University of Massachusetts Boston

Visual attention and perceptual grouping both save us from being overloaded by the vast amount of inputs: the former accomplishes by selecting specific information for further processing, and the latter by organizing a complex visual scene into reduced clusters of similar properties. It is long assumed that both attentional selection and perceptual grouping require consciousness, but this view has been challenged in recent years by empirical findings suggesting the opposite. In this study, we study whether awareness of a collinear contour is a prerequisite of its interplay with selective attention. We employed a phenomenon that attentional search was delayed when a target overlapped spatially with a collinearly grouped distractor in comparison to when a target did not overlap with the distractor (Jingling and Tseng, 2013). We first identified that visible long (= 9 elements), but not short (= 3 elements) collinear distractor slowed observers' detection of an overlapping target. Then we masked part of a long distractor (= 9 elements) with continuous flashing color patches (= 6 elements) so that the combined dichoptic percept to observers' awareness was a short collinear distractor (= 3 elements). We assessed whether the invisible parts impacted selective attention the same way as supra-threshold collinear parts. We found that the invisible collinear parts, like visible ones, could join the visible parts to form a full-length contour to impair search. This implies that collinear integration does not require awareness of all elements, and the interaction between collinear grouping and attention is likely at an early site where awareness is not critical for processing

26.549 **Task-switching mediates direct interference of intertarget distractors in the attentional blink** Alexia Ptito[1](alexia.ptito@gmail.com), Benoit Brisson[2]; [1]Université de Montréal (Psychologie), [2]Université du Québec à Trois-Rivières (Psychologie)

The attentional blink (AB) refers to the difficulty in reporting a second target (T2) when presented shortly after a first target (T1) in a rapid serial visual presentation (RSVP) of distractors. There is an ongoing debate as to the role of intertarget distractors in the AB. Some studies have proposed that intertarget distractors can only modulate the AB indirectly by affecting processing of T1. Others have suggested that intertarget distractors can modulate the AB directly, without affecting T1 processing. The goal of the present study was to investigate distractor-based interference in the AB by recording the P3 component of the event-related potential to both targets while varying intertarget events and task switching between targets. An intervening distractor was presented at lag 1 (T1 + 1), at lag 2 (T1 + 2), or at neither of these two lags (no distractor). T2 was always presented during the AB (at lag 3), and was always the last item in the RSVP stream. In two experiments, the P3 to T1 was attenuated in the T1+1 condition compared

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to the two other distractor conditions, demonstrating that the intertarget distractor interfered with T1 processing only if presented at lag 1. In absence of a task switch (Experiment 1), the P3 to T2, obtained by subtracting T1-only trials from T1+T2 trials, was delayed in both the T1+1 and T1+2 conditions compared to the no distractor condition. In the presence of a task switch (Experiment 2), the P3 to T2 was delayed only in the T1+1 condition. Results demonstrate that intertarget distractors can modulate the AB directly without affecting T1 processing, but only in absence of a task switch between targets. Implications for extant models of the AB are discussed.

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26.550 **Processing of Spatially Stationary and Moving RSVP Streams in Parafoveal Vision** Rasmus Lunau[1](rasmus.lunau@psy.ku.dk), Claus Bundesen[1]; [1]Department of Psychology, University of Copenhagen

When two targets are embedded in an RSVP stream of distractors presented to central vision, the probability of correctly identifying the second target (T2), given that the first target (T1) is correctly identified, diminishes if the targets are presented with a stimulus-onset asynchrony of less than 500 ms, a phenomenon known as the attentional blink (AB). In this study, one or more RSVP streams were presented in parafoveal vision, arranged on an imaginary circle around fixation. We investigated both processing of spatially stationary and moving RSVP streams, identical to those used in prototypical studies of ABs except that the stimulus presentation was parafoveal instead of central. In conditions with multiple RSVP streams, a cue indicating which stream contained the targets would stay still or move clockwise between the stationary streams. The results showed no evidence of attentional blinks in any of our experimental conditions, which suggests that the conditions necassery for the AB are not present in parafoveal vision.

26.551 **A temporal benefit of covert spatial orienting across visual hemifields.** Chris Angeloni[1](chris.angeloni@vanderbilt.edu), Jocelyn Sy[1], Frank Tong[1]; [1]Department of Psychology, Vanderbilt University

Recent work has demonstrated significant performance advantages in tasks spanning both visual hemifields, implicating the presence of two partially independent resources in each hemisphere that can process visual input in parallel. This effect has been demonstrated in a variety of visual domains, selectively enhancing attentional tracking (Alvarez & Cavanagh, 2005) and visual short-term memory for spatial locations (Delvenne, 2005) and also exhibiting reduced susceptibility to the attentional blink (Scalf et al., 2007). The current study examined the temporal dynamics of covert attentional orienting within and across hemifields to determine whether a similar advantage would be observed for serial shifts of attention. Participants performed a rapid serial visual presentation (RSVP) task on one of four simultaneously presented RSVP streams, each stream presented in each visual quadrant. We manipulated the direction of attentional orienting by cuing participants to first attend to one RSVP stream. Subsequently, within that stream, a cognitive cue indicated that the participant should switch their attention to a different RSVP stream that was either in the current hemifield or the opposite hemifield. Participants were instructed to report the first character that they perceived following the attentional shift to the second RSVP stream. The temporal lag between the cognitive cue and the reported letter was assumed to reflect the time needed to process the cognitive cue and to spatially reorient attention. We found a significant interaction effect between lag and the direction of attentional reorienting. Post-hoc comparisons revealed a temporal benefit in reporting letters 300ms after the cue when attention was shifted across hemifields, in comparison to when shifting within the same visual hemifield. These findings suggest that participants spatially reoriented attention more quickly across hemifields than within hemifields, supporting the notion that partially independent attentional resources in the two hemispheres can support faster shifts of attention across hemifields.

26.552 **Can Attention's Temporal Resolution Be Doubled?** Andrew Clement[1,2](aclemen3@nd.edu), Nestor Matthews[1]; [1]Department of Psychology, Denison University, [2]Department of Psychology, University of Notre Dame

Introduction: Extant research indicates that visual attention samples the environment about seven times per second (VanRullen, Carlson & Cavanagh, 2007). Research also suggests that separate neural resources mediate attention to the left and right visual fields (LVF and RVF, respectively; Alvarez & Cavanagh, 2005). Here, we investigated whether these LVF and RVF resources could operate additively to increase attention's temporal resolution. Method: Denison University undergraduates viewed bilateral-stream RSVP displays containing two successive targets (T1 and T2) and reported target identities on each trial. Four target-hemifield configurations (LL, RR, RL, LR) were varied randomly across trials. In Experiment 1, the LVF and RVF streams were either temporally synchronized or asynchronized such that new visual information appeared at either 7.5 or 15 Hz, respectively. Experiment 2 comprised the asynchronized condition from Experiment 1, along with a "triple" condition that embedded T1 and T2 within separate LVF-only or RVF-only stimulus triplets at 15 Hz. Results: Experiment 1: Doubling the visual information rate from 7.5 Hz (synchronous condition) to 15 Hz (asynchronous condition) did not impair T2|T1 accuracy (p=.162, n.s.). Also, T2|T1 accuracy for LVF-T2s significantly exceeded that for RVF-T2s (p<.001). Experiment 2: T2|T1 accuracy in the asynchronous condition significantly exceeded that in the laterally faster triple condition when both targets appeared within the same hemifield (p<.001). This effect vanished when the two targets appeared in separate hemifields. T2 accuracy also significantly exceeded T1 accuracy in the triple condition's RL hemifield configuration (p<.05), indicating a LVF advantage. Conclusion: Our findings suggest that independent LVF and RVF neural resources can cooperate to effectively double attention's temporal resolution, given appropriate stimulus conditions. Additionally, the present LVF advantages are consistent with accounts of a right parietal lobe "when" pathway (Battelli, Pascual-Leone & Cavanagh, 2007).

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26.553 **Perceptual delay in metacontrast** Jérôme Sackur[1, 2](jerome.sackur@gmail.com), David Zarebski[1], Michel Dutat[1]; [1]DEC, École Normale Supérieure, Paris, France, [2]Institut Universitaire de France, Paris, France

Metacontrast refers to the modulation of visibility of a brief target stimulus created by a surrounding, non-overlapping subsequent visual mask. Metacontrast is known not only to impair visual perception of the target, but also to impact its perceived duration and its perceived time of occurrence. In a series of experiments, we tested this effect by collecting both temporal order judgments (TOJ) and subjective ratings from naive observers. We also tested the interplay between the perceived temporal position of the target and a simple motor response to the target. Results first show a very strong agreement of TOJs and subjective ratings. Second, our results suggest that perceptual delay and visibility of the target are negatively correlated. Third, we find evidence for a motor induced perceptual delay that seems independent from the metacontrast induced perceptual delay.

Attention: Tracking

Saturday, May 17, 2:45 - 6:45 pm
Poster Session, Pavilion

26.554 **Tracking Illusory Contour Figures** Natasha Dienes[1](ndienes@uoguelph.ca), Lana Trick[1]; [1]University of Guelph

In static displays, search is inefficient when participants are looking for targets that differ from distractors in line-orientation for objects defined by Kaniza-style illusory contours (disconnected pac-men lined up to create the impression of contours); the same search is efficient for objects defined by actual (connected luminance-based) contours (e.g., Li, Cave & Wolfe, 2008). This suggests that illusory-contour defined line-orientation cues cannot guide the attentional focus to targets in the same way as the same cues can when targets are defined by actual contours, and this in turn may indicate more attentional demands when defining objects as wholes. However, it is unclear whether illusory-contour defined targets are also more difficult to track than those defined by actual contours when items move. On the one hand, the Gestalt cue "grouping by common fate" may be such a powerful indication of object-hood that it wipes out any benefit of real over illusory contours in multiple-object tracking (MOT). On the other, it is possible that static and dynamic cues both contribute to helping objects maintain their integrity during MOT; thus there may be attentional costs to having to draw together the disconnected elements in illusory-contour figures: one that may only reveal itself once the tracking task becomes demanding (with more targets). MOT performance was compared for 1, 3, and 5 targets when all items (targets and distractors) were defined by actual as compared to Kaniza-style illusory contours. In a second experiment, the task was made even more difficult by making the pac-men inducers within individual Kaniza figures differ in contrast polarity (some darker than the background and others lighter), a difference that promoted grouping parts of targets with parts of distractors in static displays (i.e., grouping by similarity in terms of contrast). Results underline similarities and differences between static and dynamic tasks.

26.555 **How long can you keep tracking?: a flying mission game**
Chuang Lyu[1](754658319@qq.com), Xuemin Zhang[2]; [1]School of psychology, Beijing Normal University, Beijing 100875, China, [2]Beijing Key Lab of Applied Experimental Psychology, School of psychology, Beijing Normal University, Beijing 100875, China

Previous research had demonstrated that observers can track up to 4 or 5 items in multiple object tracking (MOT) task. Here we proposed a new question: how long can observers maintain tracking. We used an adapted MOT task. Several (3 levels: four items, five items, six items) different blue rectangles, which represented barriers, and a red square, which represented airplane, were presented on an initial background randomly without overlapping. When participants clicked the red square, the blue ones began a rectilinear motion respectively (initial velocity had 3 levels: 7 pixel/frame, 6 pixel/frame, 5 pixel/ frame. We refreshed a frame every 16 milliseconds.) with changing speed (by ±5% each frame and ranging from (initial velocity+2) pixel to (initial velocity-2) pixel). The blue targets passed through each other, but bounced back when approaching to the boundary of the moving background, which was larger than the initial background. The red square was controlled by moving mouse. The main task was to avoid crashing with blue barriers and boundaries of initial background. We provided more rewards every ten extend minutes. Significant interactive effect and main effect of the two factors were found through repeated ANOVA. Pairwise comparisons indicated that discrepancy between different levels of two factors were all significant. In addition, the difference between four items and five items was much larger than that between five and six items. Similarly, the difference between slow speed and middle speed was much larger than middle speed and high speed. Thus, our results show that tracking time for four items is much longer than five or six items. When training for tracking, tracking more than six items or more quickly than 7 pixels/ frame might be less helpful in improving performance. This task is useful and ecological in investigating multiple object tracking.

26.556 **How do we update mental simulations at the right speed?**
Alexis Makin[1](alexis.makin@liverpool.ac.uk), Marco Bertamini[1]; [1]Psychological Sciences, University of Liverpool

People can update their mental representations whenever the world changes. Updating is usually driven by new sensory input. Interestingly, we can also update mental representations without sensory cues, and we can do this at an appropriate rate. One laboratory paradigm that may require such rate-controlled mental simulation is the motion extrapolation task, where people estimate the current position of an occluded moving object. We explored the functioning of human rate control systems across multiple extrapolation tasks. One possibility is that a common rate controller guides all dynamic updating, an alternative hypothesis is that separate rate controllers guide updating in different modalities and dimensions. In the standard motion extrapolation task, our participants viewed a target moving along a 20 degree track, and then disappear at an unpredictable point. They had to press a button when it reached the end of the track (Figure 1A). In the novel accumulation extrapolation task, participants viewed an empty space filling with gabors. The accumulation process paused before completion. Participants assumed ongoing accumulation, and then pressed when they judged that the process was complete (Figure 1B). The tasks were interleaved, and temporal parameters were matched. We found evidence that a common rate controller guided performance on both tasks. First, task parameters of stimulus velocity, occluded distance and occlusion duration influenced response time in a similar way on both tasks. Second, performance was correlated, so participants who pressed early on one task tended to do so on the other. We conclude that a common rate controller may guide all forms of mental updating. This rate controller is similar to the velocity store that putatively facilitates smooth pursuit, but with a more global function than previously envisaged.
Acknowledgement: Leverhulme Trust

26.557 **Virtual object tracking: The inference and tracking of invisible objects through effects on their surroundings**
Joshua New[1](jnew@barnard.edu), Elizabeth Han[1]; [1]Department of Psychology, Barnard College, Columbia University

Multiple object tracking (MOT) has been used to great effect in delimiting what perceptible features and behaviors are intrinsic to the representation of objects. We considered the ecological condition in which objects are conceptually instantiated and tracked prior to – or entirely without – becoming visible. For example, hidden animals are readily inferred from leaves and grasses that they brush in passing. Here, we present a novel MOT display of 'virtual' targets and distractors that are not themselves visible, but whose locations are haphazardly revealed by their displacement of numerous squares filling the display. In Experiment 1, we evaluated viewers' abilities to track from 1 up to 5 targets among ten identically-appearing objects. Viewers were able to track multiple independently-moving objects – albeit less capably than found under the conditions characteristic of previous research. The second experiment ruled out that this lower performance for tracking virtual objects resulted from the visually complex background. Under the same viewing conditions, tracking accuracy for visible targets was comparable to that in previous research and significantly greater than for virtual targets. In a third experiment, we evaluated tracking for objects visible at the outset which then all remained visible, or each briefly and completely disappeared once, or each briefly disappeared but persisted 'virtually'. Unsurprisingly, completely disappearing objects were tracked less capably than either continually visible or briefly virtual objects. However, objects that underwent virtual disappearances were tracked as well – and perhaps even better – than those remaining visible throughout the trial. Although inherently more challenging, viewers can infer and track multiple independently-moving objects from indirect evidence of their location – and absent any visible features of the objects themselves. Finally, virtual object tracking is a novel method that may be uniquely well-suited for studies otherwise at risk of confounding by lower-level visual saliency.

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26.558 **Dividing attention reduces both speed and temporal frequency limits on object tracking**
Alex Holcombe[1](alex.holcombe@sydney.edu.au), Wei-Ying Chen[1]; [1]School of Psychology, University of Sydney

Low-level motion processing is limited by temporal frequency, not speed: for a broad range of spatial frequencies, the fastest speeds at which motion is perceived correspond to a single temporal frequency, meaning that the threshold speed is proportional to the inverse of spatial frequency (Burr & Ross, 1982). Like low-level motion, attentional tracking also has a temporal frequency limit, but one that is much lower (7 Hz) and declines progressively with more targets to track. Also unlike low-level motion, attentional tracking additionally has a speed limit (Holcombe & Chen, 2013 and Verstraten et al., 2000), supporting a qualitative difference between tracking processes and low-level motion. Here, one tracking target revolved about the fixation point, along with a distractor or distractors sharing the same circular trajectory. When the number of distractors is higher than about four, and speed is increased, performance falls to threshold when a particular temporal frequency is reached. But for fewer distractors, the limiting factor instead appears to be speed. Like Verstraten et al. (2000) and Holcombe & Chen (2013), for one target we observe a limit of about 2 revolutions per second (rps). Here we varied the number of targets by presenting three concurrent, concentric displays. A second target reduced the speed limit by 0.4 rps, and a third target by a further 0.5 rps. Thus, dividing attention reduces tracking's speed limit substantially, just as it does its temporal frequency limit. Unlike the temporal frequency limit, the speed limit was not robust to changes in the number of distractors sharing the trajectory. When two rather than one distractor shared each target's trajectory, the speed limits fell by 0.5 rps. Theories of tracking must be modified if they are to explain how dividing attention reduces both limits, and additionally explain the decrease in speed limits caused by an additional distractor.
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26.559 **Action Video Game Experience Does Not Predict Multiple Object Tracking Performance**
Cary Stothart[1](cary.stothart@gmail.com), Walter Boot[1], Daniel Simons[2], Angeliki Beyko[3]; [1]Department of Psychology, Florida State University, [2]Department of Psychology, University of Illinois at Urbana-Champaign, [3]Institute of Cognitive Neuroscience & Dept. Psychology University College London

Self-reported action video game experience has been linked to better performance on many cognitive tasks, including multiple object tracking. However, the limitations of these studies preclude a reliable measure of the size of the association: (a) most used small samples (often just 10 subjects per group) and (b) many tested participants who knew they were recruited because of their gaming experience, potentially introducing demand characteristics. We explored the link between gaming experience and multiple object tracking in a pre-registered study (http://goo.gl/s6gLX7) with a substantially larger sample. Moreover, we systematically varied the method of recruitment, comparing gamers and non-gamers who were recruited either overtly (ngamers = 75, nnongamers = 84) or covertly (ngamers = 72, nnongamers = 108). Unlike previous studies, we found almost no difference in multiple object tracking accuracy between gamers (overt: 70.70%, SD = 6.30%; covert: 70.40%, SD = 7.00%) and non-gamers (overt: 70.30%, SD = 6.50%; covert: 69.10%, SD = 7.00%), regardless of recruitment method (overt: $t(156) = -.427$, $p = .670$, $d = .062$; covert: $t(177) = -1.256$, $p = .211$, $d = .186$). Not surprisingly, given the lack of a difference between gamers

and non-gamers, the method of recruiting had no effect on accuracy ($F(1, 334) = .343$, $p = .558$, $\eta 2partial = .001$). Our results suggest that the link between gaming and multiple object tracking performance is not robust

26.560 Exploration of the Halt-Move effect for occluded objects in Multiple Object Tracking: Tests of masking, cuing and item displacement

Deborah Aks[1](daks@rci.rutgers.edu), Navpreet Singh[2], Meriam Naqvi[2], Sanjana Mohan[3], Vedant Patel[3], Pylyshyn Zenon[1,4]; [1]Center for Cognitive Science, Rutgers University, [2]Biological Sciences, Rutgers University, [3]Biomedical Engineering, Rutgers University, [4]Psychology, Rutgers University

We extend earlier Multiple Object Tracking (MOT) work assessing how position-coding mediates our ability to track objects. Past studies of interrupted tracking, where items disappear briefly from view, show MOT is better when objects halt during their disappearance than when they move (Keane & Pylyshyn; 2006), and that this halt-move difference occurs even when the abruptness of item-offset is controlled (Aks et al, VSS, 2009). Here we examine further the effect of masking, cuing item interrupts, and disappearance times on MOT. Method. We compare mask vs. no-mask, and cued vs. no-cued interruptions in a standard MOT task. Eye-blinks trigger items to disappear for different durations (50 to 900ms), and changes to item movement (e.g., halt vs. move). Eye-blinks and mask control abruptness of item offset and visible persistence. In cued-MOT, subjects blink their eyes when they hear a sound probe. In no-cued MOT, subjects spontaneously blink their eyes. Results. MOT is impaired in mask and cued trials, and when items move during their disappearance. The greater the distance between the disappearance and reappearance sites (measured along a linear motion extrapolation) the greater the impairment in tracking. We report several other interactions of this distance effect such as the finding that performance drops when the disappearance time increases, but only for the Move and not the Halt condition. One unexpected result is that MOT improved with disappearance time when eye-blinks and item disappearance were not cued. Conclusions. Our results provide further support for location-coding in MOT with the main effects of distance and whether objects halt or continue moving while invisible. The unexpected improvement in no-cue trials, when eye-blinks and item-disappearance occur spontaneously, suggests an additional influence on MOT.

26.561 Studying the effect of eye-movements and interruptions in Multiple Object Tracking

Meriam Naqvi[1](mnaqvi15@gmail.com), Deborah Aks[2], Navpreet Singh[1], Sanjana Mohan[1], Chisom Emeana[1], Hannah Canuto[1], Zenon W. Pylyshyn[2]; [1]Rutgers University, [2]Rutgers University Center for Cognitive Science

Studies of disrupted multiple object tracking (MOT) have shown tracking is better the closer disappearing items are to their reappearance sites: Items that halt while hidden are easier to track than those that move (Keane & Pylyshyn, 2006). These results suggest that past object-locations are remembered when items disappear briefly from view. Here we examine where we look at MOT to learn whether a bias from eye-movements may account for better tracking when items halt during their disappearance. If gaze plays a role, than fixating the center of the screen should reduce the halt-move difference in MOT. Method. Subjects tracked 4 of 8 identical circles in a MOT task. Subjects were either free to move their eyes during tracking, or they fixated on the center of the display. Midway through each 5s trial, subjects were cued with a sound to blink their eyes . Eye-blinks triggered: (1) Items to disappear for 150, 450, or 900ms, and (2) Items to halt or move during their disappearance. The eye-blink induced disruption was used to remove the (possible confound of) abrupt offset when items disappear. Results. MOT is better when subjects are free to move their eyes than when they fixate the center of the screen. More important, both fixation conditions produce better tracking when items halt, and when disappearing items are close to their reappearance sites.Conclusions. A variety of factors can account for the impaired MOT performance when subjects fixate the center of the screen : Cognitive effort needed to sustain fixation, blurring of items in the periphery, or limitation in covert attention. More noteworthy is the robustness of the halt-move effect even when fixating the center of the display. This suggests that position-coding is not just due to eye-movements.

26.562 My Attention is Over There: A Serial Component for Multiple Object Tracking

Justin M. Ericson[1](jerics1@lsu.edu), Rebecca R. Goldstein[1], Melissa R. Beck[1]; [1]Department of Psychology, Louisiana State University

Increasing the number of changes in trajectory has been shown to negatively impact tracking accuracy (Ericson & Beck, 2013). Additionally, unexpected changes in trajectory have been known to attract attention (Howard & Holcombe, 2010). However, whether or not there is some attentional resource priority given to target items that have recently changed direction is unknown. This study examined whether attention lingers on a target after the target has changed trajectory. Previously, it was demonstrated that reaction times were faster to target probes that occurred on items that changed trajectory more frequently (Ericson, Goldstein, & Beck, VSS 13). The current study utilized a rotating tracking paradigm, four targets were paired with distractors and each target-distractor pair rotated for six revolutions. Each pair moved independently of the others and either did not change trajectory (0 change) or changed trajectory four times in a trial (4 change). In each trial, 100 ms after a change in trajectory for a target-distractor pair occurred, a single gray probe appeared on a target object for 100 ms. Participants were instructed to track the targets and press a spacebar as quickly and accurately as possible when the probe appeared. Probes appeared either on the same target that had just changed trajectory or on a different target. Results replicated previous findings showing that participants had better tracking accuracy on the 0-change trials compared to the 4-change trials. For the 4-change trials, when the probe appeared on the same target that just changed trajectory, probe detection was significantly better than in the 0-change trials, and was also better than when the probe appeared on a different item in the 4-change trials. This demonstrates that attention is preferentially allocated to a target item when it changes trajectory, suggesting a serial processing component in multiple object tracking.

26.563 The effect of feedback on 3D multiple object tracking performance and its transferability to other attentional tasks

Chiara Perico[1,2](chiara.perico@mail.mcgill.ca), Domenico Tullo[1,2], Krista Perrotti[1] , Jocelyn Faubert[3,4], Armando Bertone[1,2]; [1]McGill University, [2]Perceptual Neuroscience Laboratory in Autism and Development, [3]Université de Montréal, [4]Visual Psychophysics and Perception Laboratory

Attentional processes play an integral role in learning, affecting performance on most cognitive tasks. In addition, feedback - instant information delivered to the individual that guides their subsequent behavior in relevant situations - plays a critical role in the efficiency and quality of learning. However, its effects are not often empirically assessed. Multiple Object Tracking (MOT) tasks were developed to objectively assess real world attention, and have been used as cognitive training paradigms geared at improving attentional abilities. With training, there is a significant improvement in MOT performance; however, little is known about the transferability of attentional capacities from MOT tasks to similar cognitive tasks. The goal of this study was thus to assess whether performance on attentional capacities acquired during training on a 3D MOT task are transferrable to other measures of attention. The role of feedback was also investigated to determine whether performance, and its subsequent transferability to other measures, is affected by feedback. Forty typically developing adults participated in 4 testing sessions on consecutive days. On day 1, intellectual and attentional abilities were assessed along with a baseline measure of MOT without feedback. Participants were split into 2 experimental groups and assessed for three subsequent days (days 2 through 4): one group received feedback during the MOT task trials; the other group received no feedback. On day 4, all participants were re-assessed on the same attentional measures as well as the MOT to determine improvements from day 1. MOT performance resulted significantly higher for the feedback group, as defined by an increased speed threshold for tracking 4 out of 8 items. The feedback group also revealed better transferability to other cognitive tasks. The results indicate that feedback is an important component during a learning regiment and that it may affect transferability of cognitive abilities.

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26.564 Replacing the spotlight with a Kalman filter: A prediction error model of multiple object tracking

Ashley M. Sherman[1](ashley.sherman@stonybrook.edu), Tomás F. Yago Vicente[2], Gregory J. Zelinsky[1,2]; [1]Department of Psychology, Stony Brook University, [2]Department of Computer Science, Stony Brook University

Does multiple object tracking (MOT) rely on the predicted motion of an object? We addressed this using a continuous tracking paradigm (Exp 1), in which observers tracked 4 of 10 dots moving at 8º/s for 8s. On each 16.6ms frame, all dots had a .025 probability of turning 0º, 15º, 30º, 45º, 60º, 75º, or 90º in either direction (held constant within a trial, but varied across trials). Performance was best in the 0º condition, and declined as turn angle increased ($p =.003$). We used Kalman filters to model this effect of motion predictability on tracking by estimating the distance between a target's predicted and actual location, creating a "prediction field". Assuming an independent filter attached to each target, and that the probability of a swapping error increases with the number of times a distractor passes into a target's prediction field, we computed a swap potential for each target and averaged these to obtain a mean swap potential. We found that swap potential correlated

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highly with performance in Exp 1 (r = -.89, p <.01). We then tested our model on two other factors known to affect MOT performance: item speed (Exp 2), and trial duration (Exp 3). In Exp 2, speed ranged from 5-11º/s (p <.001). In Exp 3, speed was held constant at 8º/s, and duration ranged from 4-12s (p <.001). Both Exps 2 and 3 used a turn angle of 0º. We again found a high correlation between performance and swap potential (Exp 2: r = -.96, p =.001; Exp 3: r = -.95, p =.001). Taken together, these results not only suggest that observers are sensitive to the predictability of an item's motion, but also that a simple model of swapping potential built from prediction errors can estimate relative performance across a number of tracking tasks.

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26.565 **The capacity of mental rotation** Yangqing Lucie Xu[1](xuy@u.northwestern.edu), Steven Franconeri[1]; [1]Northwestern University

Although mental rotation is one of the most studied topics in visual cognition, we still know little about how our visual system constructs a rotated view. One fundamental unanswered question surrounds the capacity of this rotation operation - how much visual information can we transform at once? Past work has tested relatively complex objects, likely rotated across complex multi-step operations, making it difficult to isolate the capacity of any individual step. Meanwhile, work using simpler displays (e.g. colored squares) in the selective tracking and visual memory literatures has made capacity estimates more measurable. We predicted that if a mental rotation task were similarly simplified, we could for the first time obtain capacity estimates for this task. Participants stored a multi-feature object (a pinwheel with four distinctly colored 'petals') in memory. Capacity for detecting feature swaps was similar to past estimates for this type of change, around 2 feature-part bindings. But when the task was altered to require mental rotation of the object to a depicted degree, capacity plummeted to just 1. But which one? We hypothesized that people chose one part of an object to act as the gauge for rotation magnitude (the 'needle' of the 'protractor'), and would remember only the feature of that part. Eyetracking revealed that people systematically guided their gaze along the imagined track of the top petal. The degree to which they followed this strategy had a strikingly large impact on their performance on the task, predicting more than 30% of the variance in individual differences. Furthermore, changes to this top part accounted for almost all noticed changes - swaps involving the non-tracked part were noticed at chance levels. Mental rotation can be a deeply capacity-limited operation, potentially limited to rotation of only a single part of an object at a time.

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Scene perception: Spatial and temporal factors

Saturday, May 17, 2:45 - 6:45 pm
Poster Session, Pavilion

26.566 **Prediction of perceived fog density and defogging of natural foggy images** Lark Kwon Choi[1,3](larkkwonchoi@utexas.edu), Jaehee You[2], Alan Bovik[1,3]; [1]Department of Electrical and Computer Engineering, The University of Texas at Austin, [2]Department of Electronic and Electrical Engineering, Hongik University , [3]Center for Perceptual Systems, The University of Texas at Austin

The perception of outdoor natural scenes is important for successfully participating in visual activities. When fog is present, however, visibility can be severely degraded. We have created a perceptual fog density index that seeks to predict the degree of visibility of a foggy scene using 'fog aware' features learned from a representative database of foggy and fog-free images. The features that define the fog density index derive from a spatial natural scene statistics (NSS) model and from observed characteristics of foggy images. We have found that the statistics of fog aware features consistently change as a function of fog density. A perceptual fog density model was derived by collecting patches from natural foggy and fog-free images, then computing pertinent NSS fog aware features from these patches to develop a perceptual fog density prediction model. A multivariate Gaussian (MVG) distribution is used to form a probabilistic feature model. In practice the perceived fog density of an arbitrary test image is predicted using a Mahalanobis-like distance measure between the 'fog aware' statistics of the test image and the MVG models obtained from the natural foggy and fog-free images. We also conducted a human study of perceived fog density. When applied to 100 natural foggy images, the predicted perceived fog density was found to correlate well with the human judgments of fog density. We have also found that the fog aware statistical features can be used to defog and thereby enhance the visibility of foggy scenes. We first produced white-balanced and contrast-enhanced images from a foggy image using the predicted visibility degree. We then selectively filtered these images with fog aware weighted maps representing distances from the statistics of fog-free images at each fog aware feature. Finally, we applied a Laplacian multi-scale pyramidal refinement to achieve a halo-free defogged image.

Acknowledgement: This work (Grants No. C0014365) was supported by Business for Cooperative R&D between Industry, Academy, and Research Institute funded Korea Small and Medium Business Administration in 2012.

26.567 **Does RMS contrast normalization impair coarse-to-fine processing of natural scenes?** Louise Kauffmann[1,2](louise.kauffmann@gmail.com), Alan Chauvin[1,2], Nathalie Guyader[3], Stephen Ramanoël[1,2,4], Carole Peyrin[1,2]; [1]Univ. Grenoble Alpes, LPNC, F-38040 Grenoble, [2]CNRS, LPNC UMR5105, F-38040 Grenoble, [3]Univ. Grenoble Alpes, GIPSA-lab, F-38402 Grenoble, [4]INSERM U836, GIN, F-38706 Grenoble

Visual analysis starts with the parallel extraction of different attributes at different spatial frequencies (SF) following a predominant and default coarse-to-fine processing sequence. Low spatial frequencies (LSF) would be processed faster than high spatial frequencies (HSF), allowing an initial coarse parsing of the visual input, before the analysis of the finer information. Studies investigating SF processing commonly use SF-filtered images as stimuli. Since LSF and HSF differ not only in terms of SF, but also in terms of luminance and contrast, recent studies normalized RMS contrast of images (i.e. the standard deviation of luminance values) in order to avoid any confound between SF components and known effects of luminance and contrast. In the present study, we investigated whether RMS contrast normalization of filtered scenes would induce bias in the default coarse-to-fine processing strategy during a categorization task (indoor vs. outdoor). We used dynamic sequences as stimuli composed of bandpass-filtered versions of a scene, presented from LSF to HSF or from HSF to LSF, allowing us to impose a coarse-to-fine (CtF) or a fine-to-coarse (FtC) processing of the scenes. In one condition (LUM), only the mean luminance of the filtered scenes was equated. In the other condition (RMS), both the mean luminance and the RMS contrast were equalized across the filtered scenes. In the LUM condition, CtF sequences were categorized faster than FtC sequences, consistent with a considerable number of studies. However, in the RMS condition, there was no advantage of CtF over FtC processing. The present study thus suggests that RMS contrast normalization of filtered scenes induces changes in the default SF processing strategies. We argue that such manipulation modify scene spectral properties that are exploited by the visual system to enable recognition. RMS contrast normalization should thus be used with caution when investigating SF processing of natural scenes.

Acknowledgement: Région Rhône-Alpes (ARC2 and Cible Grants)

26.568 **Through the Looking-Glass: Are objects in mirrors really objects?** Preeti Sareen[1,2](preesar09@gmail.com), Krista A. Ehinger[1,2], Jeremy M. Wolfe[1,2]; [1]Harvard Medical School, [2]Brigham & Women's Hospital

Mirrors are common in our everyday visual environment. We use visual information reflected from mirrors for various purposes, like gauging traffic while driving or grooming every morning, but are mirror-reflected objects treated in the same way as real objects? We showed 44 pictures of indoor scenes to 11 observers and asked them to label "everything they saw." Observers freely viewed one scene at a time and labeled as much or as little as they wanted before moving on to the next scene. They were encouraged to take no more than two minutes per scene. A subset of images was selected specifically for the presence of mirrors with objects visible in those mirrors. Other scenes served to prevent observers from guessing our specific interest in mirrors. Labeling involved clicking on an object to mark its location and entering a text label (e.g., table). Observers placed an average of 16.3 labels per image. In 21 images, an object (e.g., towel) appeared in the room and in the reflection at approximately the same size and image quality. The objects in the room received an average of 8.1 labels. The same objects, reflected in a mirror, were labeled just 0.9 times on average (t(20) = 12.0, p <0.00001). Objects that only appeared as reflections (not visible otherwise), were labeled more often than the objects that appeared both as reflections and in the room. However, such objects were never the most labeled objects in a scene. It might be objected that an object in the room is more "real" than its reflection but in both cases, neither object is real.

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Both are parts of a photograph. Apparently, the parts of the photograph that represent reflections are somewhat less "real" than the rest, which has interesting implications for visual attention and scene perception.

Acknowledgement: PS was supported by DFG (German Research Foundation) Research Fellowship

26.569 **Towards a model for mid-level feature representation of scenes** Mariya Toneva[1](mariya.toneva@yale.edu), Elissa Aminoff[2], Abhinav Gupta[3], Michael Tarr[2,4]; [1]Department of Computer Science, Yale University, [2]Center for the Neural Basis of Cognition, Carnegie Mellon University, [3]The Robotics Institute, School of Computer Science, Carnegie Mellon University, [4]Department of Psychology, Carnegie Mellon University

Never Ending Image Learner (NEIL) is a semi-supervised learning algorithm that continuously pulls images from the web and learns relationships among them. NEIL has classified over 400,000 images into 917 scene categories using 84 dimensions - termed "attributes". These attributes roughly correspond to mid-level visual features whose differential combinations define a large scene space. As such, NEIL's small set of attributes offers a candidate model for the psychological and neural representation of scenes. To investigate this, we tested for significant similarities between the structure of scene space defined by NEIL and the structure of scene space defined by patterns of human BOLD responses as measured by fMRI. The specific scenes in our study were selected by reducing the number of attributes to the 39 that best accounted for variance in NEIL's scene-attribute co-classification scores. Fifty scene categories were then selected such that each category scored highly on a different set of at most 3 of the 39 attributes. We then selected the two most representative images of the corresponding high-scoring attributes from each scene category, resulting in a total of 100 stimuli used. Canonical correlation analyses (CCA) was used to test the relationship between measured BOLD patterns within the functionally-defined parahippocampal region and NEIL's representation of each stimulus as a vector containing stimulus-attribute co-classification scores on the 39 attributes. CCA revealed significant similarity between the local structures of the fMRI data and the NEIL representations for all participants. In contrast, neither the entire set of 84 attributes nor 39 randomly-chosen attributes produced significant results using this CCA method. Overall, our results indicate that subsets of the attributes learned by NEIL are effective in accounting for variation in the neural encoding of scenes – as such they represent a first pass compositional model of mid-level features for scene representation.

Acknowledgement: the Office of Naval Research MURI contract N000141010934

26.570 **Place recognition and heading retrieval are dissociable in mice (and possibly men)** Joshua B. Julian[1](jjulian@sas.upenn.edu), Alexander Keinath[1], Isabel Muzzio[1], Russell A. Epstein[1]; [1]Department of Psychology, University of Pennsylvania

A navigator who becomes lost must identify her current location and recover her facing direction in order to restore her bearings. We tested the idea that these two tasks—place recognition and heading retrieval—might be mediated by distinct cognitive systems. Previous work has shown that both rodents and young children rely primarily on the geometric shape of navigable space to regain their sense of direction after disorientation, often ignoring non-geometric visual cues even when they are informative (Cheng, 1986; Hermer & Spelke, 1994). Notably, these experiments are almost always performed in single-chamber environments in which there is no ambiguity about place identity. We examined the navigational behavior of disoriented mice presented alternately with two rectangular chambers that were geometrically identical but distinguishable by horizontal or vertical stripes along one wall. Thus, the stripes could be used both to identify the chambers (place recognition) and also to disambiguate directions within the chambers (heading retrieval). In one chamber, mice were rewarded whenever they searched in the left corner nearest the striped wall, and in the other chamber, whenever they searched in the right corner nearest the striped wall. We found that in each chamber mice searched in the correct corner for that chamber or its geometrical equivalent (diagonally opposite) corner with equal frequency, and did so significantly more often than at the other corners. Thus, mice used the stripes to identify the chamber in which they were located, but not to disambiguate between the two geometrically-equivalent facing directions. These results suggest the existence of separate systems for place recognition and heading retrieval in mice that are differentially sensitive to geometric vs. non-geometric visual cues. We speculate that a similar cognitive architecture may underlie human navigational behavior.

Acknowledgement: NIH (R01 EY-022350) and NSF (SBE-0541957)

26.571 **Modeling Visual Clutter Perception using Proto-Object Segmentation** Chen-Ping Yu[1](cxy7452@gmail.com), Dimitris Samaras[1], Gregory Zelinsky[1,2]; [1]Department of Computer Science, Stony Brook University, [2]Department of Psychology, Stony Brook University

We introduce the Proto-object model of visual clutter perception. This unsupervised model segments an image into superpixels, then merges neighboring superpixels that share a common color cluster to obtain proto-objects, defined here as spatially extended regions of coherent features. Clutter is estimated by a simple count of the number of proto-objects. We tested this model using 90 images of realistic scenes selected from the SUN09 image collection to have objects ranging in number from 1-60 (as determined by the supplied object ground truth). We then had 15 observers individually rank order these scenes from least to most visually cluttered, then took the median of these rankings to obtain a single behavioral ranking. Comparing this behavioral ranking to a second ranking based on the model's clutter estimates, we found that the two correlated highly (Spearman's $\rho = .804$, $p < .001$). Follow-up analyses also showed that the Proto-object model was highly robust to changes in its parameters and was generalizable to unseen images, as determined by 10-fold cross validation. We compared the Proto-object model to six other models of clutter perception and demonstrated that it outperformed each—in some cases dramatically. Importantly, we also showed that the Proto-object model was a better predictor of clutter perception than an actual count of the number of objects in the scenes, suggesting that the "set size" of a scene may be better described by proto-objects than objects. We conclude that the success of the Proto-Object model, the new standard for models of clutter perception, is due in part to its use of an intermediate level of visual representation—one between features and objects—and that this is evidence for the potential importance of a proto-object representation in many common visual percepts and tasks.

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26.572 **Using spatial statistics to investigate allocation of attention within single trials** Hans Trukenbrod[1](Hans.Trukenbrod@uni-potsdam.de), Ralf Engbert[1]; [1]Department of Psychology, University of Potsdam

Due to visual acuity limitations of the retina, we need to move our eyes when exploring a visual scene. As a result, we usually observe clusters of fixations in some parts of the image. Both bottom-up (e.g., salience) and top-down factors (e.g., gist of a scene) have been put forward to explain the generation of fixation clusters. Here, we show that target selection is not only a consequence of image properties but also depends on the size of the attentional window – a stimulus-independent mechanism. We demonstrate that the inhomogeneous pair correlation function (PCF) can be used to investigate distributions of fixation locations during single trials, independent of the inhomogeneity generated by images. Our results show that fixations cluster at short length scales (<3°) during single trials. The effect cannot be explained by the overall inhomogeneity of fixations locations generated across subjects. Presenting the same image twice augmented the effect. The PCF can be interpreted as an indicator of the size of the attentional window that decreases during reinspection of images. In general, the limited attentional window reinforces inspection of close fixation locations. We conclude that the PCF is a promising tool to investigate dynamics of target selection during individual trials.

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26.573 **Why the "Rule of Thirds" is Wrong** Stephen Palmer[1](palmer@cogsci.berkeley.edu), Yurika Hara[2], William Griscom[1]; [1]Psychology, U. C. Berkeley, [2]Molecular & Cell Biology, U. C. Berkeley

Perhaps the best-known prescriptive rule of pictorial composition is the "rule of thirds" (ROT), which posits that: (a) the best positions for the focal object within a rectangular frame lie along the vertical and horizontal lines that divide the frame into thirds, with maxima at the four intersections of these third-lines, and (b) the worst positions lie along the vertical and horizontal axes of symmetry, with the minimum being at the frame's center. We tested these predictions by measuring people's preferences for placement of a single object at the nine points defined by the 3x3 grid of intersections among the horizontal and vertical third-lines and symmetry-axes. We measured forced-choices between two pictures of the same object (fish/dog/eagle) facing in the same direction (forward/leftward/rightward) at all possible pairs of positions in the 3x3 grid. The results strongly contradicted both of the ROT's main claims. The most preferred position for every object in every facing direction was the frame's center, consistent with a pronounced center bias (Palmer, Gardner & Wickens,

2008). This bias was strongest when symmetrical objects faced forward. Preference for horizontal placement of left-facing and right-facing objects was biased asymmetrically away from the center, toward the side opposite the facing direction, consistent with an inward bias (Palmer et al., 2008). Vertical biases were much less pronounced, but people tended to prefer the flying eagle to be higher in the frame, consistent with an ecological bias toward its viewer-relative position in the environment (Sammartino & Palmer, 2011). Further results show that these biases can be modulated by a second visual element at other background locations within the frame. We conclude that, although the ROT is empirically incorrect, it may be heuristically useful in encouraging artists to use off-center focal-object locations when those placements "work" in the context of the entire image.

Acknowledgement: National Science Foundation, Google

26.574 **Analysis of Fused and Unfused Imagery using Systems Factorial Technology (SFT)** Elizabeth Fox[1](fox.119@wright.edu), Joseph Houpt[1], Fairul Mohd-Zaid[2], Jennifer Bittner[3]; [1]Wright State University, [2]Air Force Institute of Technology, [3]Ball Aerospace

Several types of sensors are used to capture imagery to provide information to human observers. Images from each sensor can be presented to an observer individually, or the images from multiple sensors can be algorithmically combined into a single image. The various algorithms for fusing images have been studied from an information theoretic viewpoint, but the advantages (or disadvantages) of fusion for human perceptual and cognitive processing have received relatively little attention. Systems Factorial Technology (SFT; Townsend & Nozawa, 1995) is general framework for assessing of how human observers process multiple sources of information. We applied SFT to measure how observers perform with images from different sensors separately (side-by-side). This performance was used as a baseline to compare performance with fused imagery. Because there are two separate images in the side-by-side presentation, there may be some statistical facilitation of the processing times, while fused presentations eliminate the need to attend to both sides. These two potential gains seem to trade off we found roughly equivalent workload capacity levels, limited for all participants, in both conditions. The survivor interaction contrast (SIC), another measure of SFT, indicated most individuals processed the side-by-side images sources of information simultaneously (in parallel) while responding with the first completed source. Despite the roughly equal capacity, the fused images result in slightly faster response times than the redundant side by side images at the group level, with all sensor types being equally fast with no significant interaction. While the fused imagery is processed slightly faster, performance with the side-by-side presentation is quite good because participants were able to process the images in parallel. Given that there is necessarily some loss of information in the fused images, it may be use side-by-side images even in time critical applications.

Acknowledgement: Air Force Office of Scientific Research

26.575 **Intrinsic Reference System in Implicit Spatial Learning: Evidence from Contextual Cueing Paradigm** Shiyi Li[1](elevenny@163.com), Zhongting Wang[1], Chao Wang[1], Limeng Shi[1], Haibo Yang[1], Xuejun Bai[1], Hong-Jin Sun[2]; [1]Academy of Psychology and Behaviour, Tianjin Normal University, China, [2]Department of Psychology, Neuroscience, and Behaviour, McMaster University, Canada

It has been proposed (Mou etal, 2004) that for memory of a scene, the structure of the object layout or environment could be used to form a reference direction which aids spatial learning. Here we evaluated the effect of various indicators of reference direction in facilitating implicit spatial learning. We used a contextual cueing paradigm where repeated configurations of random elements induce faster search performance than novel configurations. We examined search behavior in a computer rendered illustrations of a 3D scene. Human participants viewed a scene consisted of an array of either different "stools" or different "chairs" randomly positioned on the ground and in their normal upright orientation. The stools were made of various circular structures so that the side view of the stool appeared to be the same from different viewpoints. The chairs were created by adding a "back" portion on top of the stools. The back of chairs provided orientation information of the objects and the scene (with coherent orientations for all the chairs). Observers searched for and identified a target positioned on the seat of a stool or a chair. The learning effect was indicated by (1) the magnitude of contextual cueing effect in a given block and (2) number of learning blocks needed to reach significant difference between repeated and novel scene. We found greater learning effect (i) when the orientation of all chairs was coherent compared to random (ii) for the chair scene with coherent orientation compared to the stool scene. However greater learning effect was not found when we introduced environmental cue for reference direction (parallel lines on the floor) to the stool scene. The results indicted that implicit spatial learning can be facilitated by the availability of intrinsic axis provided by individual objects in the scene but not from external environmental indicators.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada (NSERC)

26.576 **Viewpoint Independence in Implicit Scene Learning Revealed in a Contextual Cueing Paradigm** Zhongting Wang[1](z-twangsunday@163.com), Shiyi Li[1], Chao Wang[1], Limeng Shi[1], Haibo Yang[1], Xuejun Bai[1], Hong-Jin Sun[2]; [1]Academy of Psychology and Behaviour, Tianjin Normal University, China, [2]Department of Psychology, Neuroscience, and Behaviour, McMaster University, Canada

For a 3D scene, whether implicit spatial learning in a contextual cueing paradigm can be transferred to a different viewpoint has not been well studied (but see Chua and Chun, 2003). In this study we examined this question using a computer rendered illustration of 3D scenes. Participants viewed a scene consisted of an array of either different "stools" or different "chairs" randomly positioned on the ground and in their normal upright orientation. The stools were made of various circular structures so that the side view of the stool appeared to be the same from different viewpoints. The chairs were created by adding a "back" portion on top of the stools. The back of the chairs provided orientation information of the objects and the scene (with all the chairs having a coherent orientation). Observers searched for and identified a target positioned on the seat of a stool or a chair. Significant contextual cuing effect was found in the training session, with faster RTs in the repeated condition than in the novel condition. In the testing session, when the viewpoints of the scene (1) remained the same, or (2) switched 45 degree for the chair scene, the contextual cueing effect was comparable to that at the end of training phase. However, for the stool scene, after 45 degree view shift, the contextual cuing effect diminished. Our results suggest that when the scene contained clear indication of the viewpoint change (from individual chairs), the spatial relation learned during training can be mentally transformed to a new viewpoint. When such indication of view change is missing, the learning can not be transferred to the new viewpoint. Moreover the ordinal information between different objects alone (as in the stool scene) would not be able to explain the viewpoint independence found in the chair scene.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada (NSERC)

26.577 **Inhibition of attention to irrelevant areas of a scene: Investigating mechanisms of attention during visual search** Effie Pereira[1](effie.pereira@queensu.ca), Yu Qing Liu[1], Monica Castelhano[1]; [1]Department of Psychology, Queen's University

Numerous studies have shown that scene context aids search due to expectations about where objects are located (Castelhano & Heaven, 2011; Neider & Zelinsky, 2006). However, it is unclear what attentional mechanisms are involved in directing gaze to target-relevant scene regions, and whether in addition to enhancing target-relevant regions, target-irrelevant regions are inhibited. In the present study, we investigated whether previously-inhibited regions of a scene would interfere with a subsequent search. Participants performed six searches for six different objects within the same image. The sixth search was always for the same object, but the first five searches could be for objects in the same context region (Same condition) or in a different region (Different condition). In the Control condition, participants did not perform a search and viewed images for 2s each for the first five trials (thus not enhancing nor inhibiting any scene regions). Analyses were performed only on the sixth search, and target-relevant regions (upper, middle, lower) were counterbalanced across all conditions. If attention is inhibited in target-irrelevant regions, then we would expect the Different condition would show longer processing times and less effective fixation placement during initial search guidance. Latency to the first saccade was significantly longer in the Different than in the Control condition. We also found that significantly fewer first fixations were placed in target-relevant regions in the Different condition than in either the Same or Control conditions. Additionally, the frequency with which initial saccades were directed towards the target were much lower in the Different condition than in either the Same or Control conditions. The pattern of results is consistent with the inhibition of target-irrelevant regions; therefore, we conclude that inhibition is a likely additional mechanism by which gaze is directed in scenes and is worthy of further study.

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University Advisory Research Council to MSC, and the Queen Elizabeth II Graduate Scholarship in Science and Technology to EJP

26.578 Using V1-Based Models for Change Detection in Natural Scenes

Pei Ying Chua[1](cpeiying@dso.org.sg), Kenneth Kwok[1]; [1]DSO National Laboratories, Singapore

Using models of the visual system, it is possible to investigate the features of human visual processing that enable sensitive and accurate change detection across a range of ambient conditions. V1-based models were used to detect the presence or absence of changes in natural scenes. All models were based on the same basic constructs of the human visual system, incorporating mechanisms of visual processing such as colour opponency, receptive field tuning, linear and non-linear behaviour, and response pooling. The natural scene images were obtained from from the publicly available Change Detection Benchmark Dataset (Bourdis, Marraud, & Sahbi, 2011). The models' performances were evaluated by their sensitivity and accuracy in correctly detecting the presence or absence of changes in the given scene. Previously, we found that models which were tuned to be more sensitive to high spatial frequencies were both more accurate and sensitive, likely because high spatial frequencies represent the fine details within the image and would thus have a greater probability of containing information about the presence of targets. Here, we studied this in greater detail by changing the size of the receptive fields as well, and found that using smaller receptive fields increased a model's sensitivity, possibly because smaller fields are more sensitive to small changes. Another feature that was studied was the effects of an attention spotlight. Implementation of a single stationary attention spotlight resulted in poor performance, whilst allowing the model to shift attention and consider cues from all regions of the image equally gave much better performance.

26.579 Complimentary roles for eye and head movements in scene viewing

Grayden Solman[1](grayden@psych.ubc.ca), Tom Foulsham[2], Alan Kingstone[1]; [1]Psychology, University of British Columbia, CAN, [2]Psychology, University of Essex, UK

The (over)abundance of information available in natural scenes, coupled with the limitations of the visual system, necessitate sequential selection of sub regions to visually attend to and process, through saccades and other orienting behaviors. In the context of eye movements, recent research has examined how spatial imbalances in the information available near fixation influences the spatial distribution of saccades, demonstrating that saccades are preferentially directed in line with available features, rather than actively sampling information-poor directions (Foulsham, Teszka, & Kingstone, 2011, AP&P). In the present experiments, we extend this paradigm to head-driven orienting behaviors, and to coupled head-and-eye movements. Participants viewed various naturalistic scenes with either full vision, or in one of three gaze-contingent conditions: with a square window, with a horizontally oriented rectangular window, or with a vertically oriented rectangular window. We present evidence that the head and eyes treat information imbalances in a complementary fashion. In particular, while saccades are preferentially aligned with the long axis of rectangular windows (e.g., more vertical saccades with a vertical window), head movements appear preferentially aligned in the orthogonal direction (e.g., more horizontal saccades with a vertical window). These findings suggest complimentary drivers in naturalistic orienting, with head movements biased toward revealing new information, and eye movements biased toward refining existing knowledge.

Acknowledgement: NSERC Killam Trust

26.580 Short term and baseline effect in the estimation of probabilistic visual event sequences

József Arató[1](arato_jozsef@ceu-budapest.edu), József Fiser[1]; [1]Department of Cognitive Science, Central European University

To understand how people build probabilistic internal representations of their dynamic perceptual environment, it is essential to know how the statistical structure of event sequences is encoded in the brain. Previous attempts either characterized this encoding by the structure of the preceding short-term repetition/alternations or, while they acknowledged the importance of long-term baseline probabilities, they failed to manipulate the baseline statistics properly to explore their effect. We investigated how expectations about the probability of a visual event are affected by varying short-term and unbalanced baseline statistics of their sequential appearance. Participants (N=19) observed sequences of visual presence-absence events and reported about their beliefs by two means: by quickly pressing a key indicating whether or not an object appeared and by giving interspersed numerical estimates of the appearance probability of the event together with their confidence of their answer. Stimuli appeared at random with the baseline probabilities systematically manipulated throughout the experiment. We found that reaction times (RTs) for visual events did not depend exclusively on short-term patterns but were reliably influenced by the baseline appearance probabilities independent of the local history. Error rates, RTs and explicit estimates were similarly influenced by the baseline: subjects were more accurate estimating the probability of very likely and very unlikely events. Furthermore, we found that subjects' report of their confidence was systematically related to both their implicit and explicit accuracy measures. Finally, reaction times could be explained by a combined effect of short-term and baseline statistics of the observed events. These results indicate that the perception of probabilistic visual events in a dynamic visual environment is influenced by short-term patterns as well as automatically extracted statistics acquired on the long run. Our findings lend support to proposals that explain behavioral changes based on internal probabilistic models rather than on local adaptation mechanisms.

26.581 The Time-Course of Scene and Action Categorization in Dynamic Videos

Adam Larson[1](larson@findlay.edu), Hope Tebbe[1], Lester Loschky[2]; [1]Psychology Department, University of Findlay, [2]Department of Psychological Sciences, Kansas State University

When watching movies, viewers' comprehension begins by constructing a working memory representation, called an event model (Zacks, et al., 2007). Our previous research has examined how these models are constructed by measuring the time-course of scene and action categorization (Larson, Hendry, & Loschky, 2012). The results support a coarse-to-fine order of categorization such that at early processing times, Superordinate scene categorization (e.g., Indoor vs. Outdoors) was better than Basic level scene categorization (e.g., Yard vs. Park), which was better than Basic level action categorization (e.g., Raking vs. Mowing), suggesting that event model construction begins with the superordinate scene category. However, action categorization performance could have been reduced due to the lack of biological motion information in static scene images. Thus, the current study examined the time-course of scene and action categorization in dynamic scene videos. Hypotheses: The onset of motion often captures attention (Abrams & Christ, 2003), which together with biological motion information could result in an early advantage for action categorization. Conversely, categorization might occur in a coarse-to-fine fashion, consistent with our previous research (Loschky & Larson, 2010). We tested these competing hypotheses by randomly assigning participants to one of three categorization conditions (Superordinate scene, Basic scene, or Basic Action). Eye-tracking and visual masking were used to manipulate processing time, which varied from sub-fixations (33 ms and 200 ms SOA) to fixations (1, 2, 3, and 4 fixations). A valid or invalid post-cue (category label) was then presented, which required a "Yes" or "No" response. The results showed a coarse-to-fine categorization order. At sub-fixation processing times, performance was best for Superordinate scene categorization and worst for Basic level action categorization. However, all categorization tasks reached ceiling performance within one fixation. Results are consistent with the hypothesis that the superordinate scene category is used first to construct an event model.

26.582 Visual features that repeat across cuts guide attention in movies

Christian Valuch[1](christian.valuch@univie.ac.at), Peter König[2], Ansorge Ulrich[1,2]; [1]Faculty of Psychology, University of Vienna, Austria, [2]Institute of Cognitive Science, University of Osnabrück, Germany

Movies contain cuts, i.e. abrupt transitions from one image to the next. Research suggests that 'continuity editing' masks cuts. For instance, within-scene cuts (WSCs) have a higher visual similarity of pre-cut and post-cut images and are more difficult to spot than between-scene cuts (BSCs). Here, we tested whether visual attention plays a role in this effect: Is attention attracted by features that repeat across cuts? We deliberately inserted WSCs and BSCs in a set of 20 sports movies. A comparison of feature distributions verified higher similarity in WSCs than BSCs. Participants saw two different movies side by side on a single computer screen. In the first experiment a cue defined the target movie that participants had to attend to. When a cut occurred the movies were stopped for a filler task. Afterwards the movies continued either at the same positions, or switched positions. Saccades to the target movie were initiated significantly faster and saccades to the wrong movie were less frequent following WSCs as compared to BSCs. In the second experiment, participants fixated the screen center and only covertly attended to the target movie, without moving their eyes. Following each cut, we briefly flashed digits on both movies and participants manually reported the identity of the digit on the target movie. Again, performance was significantly better after WSCs than BSCs. In both experiments, we also found that repeating the position of the target movie strongly improved performance on top of the facilitative effect of visual feature repetition. We discuss our results with regard to intertrial priming of attention, usually studied with simpler and better controlled displays, but probably the process responsible for the continuity effect.

Acknowledgement: Supported by grants from the Wiener Wissenschafts-,Forschungs-, und Technologiefonds (WWTF, ViennaScience and Technology Fund)

26.583 **Coloring Time! The Effect of Color in Pictures on Time Perception** Jason Hays[1](jason_hays22@mymail.eku.edu), Brian Huybers[1], Alex Varakin[1]; [1]Eastern Kentucky University

Past research suggests that scrambling scene structure influences the subjective durations of scenes (Varakin, Klemes, & Porter, 2013, QJEP). The present experiments tested the effects of color on duration judgments of scenes using a temporal bisection task. In Experiment 1 (n = 25), on each trial, an image appeared for one of several pre-chosen durations between 400ms and 1600ms. Participants judged whether the duration was closer to a pre-learned short (400ms) or long (1600ms) standard. Two types of scenes were presented: black-and-white (BW) or color. To evaluate differences in subjective durations, bisection points were calculated separately for each scene type for each participant. A bisection point is the duration at which 50% of responses are predicted to be "long," thus, a decrease in the bisection point implies an increase in subjective duration. In Experiment 1, there was no difference between the average bisection point for the color (M = 1008ms, SD = 229ms) and BW scenes (M = 1021ms, SD = 188ms): $t(24) = 0.56$, $p > .05$. In Experiment 2 (n = 26), we wanted to ensure that participants attended to color. The method was similar to Experiment 1, except that on some trials, participants categorized scenes as BW or color. On remaining trials, they did the temporal bisection task as in Experiment 1. Participants did not know which task they needed to perform until the end of the trial, and therefore had to pay attention to both duration and color. In Experiment 2, the average bisection point for BW scenes (M = 1036ms, SD = 213ms) was higher than for colored scenes (M = 977ms, SD = 154ms): $t(25) = -2.47$, $p < .05$. Together, these results suggest that color scenes seem to last longer than BW scenes, but only when participants pay attention to color information.

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Sunday Morning Talks

Binocular Vision

Sunday, May 18, 8:15 - 9:45 am
Talk Session, Talk Room 1
Moderator: Cheryl Olman

31.11, *8:15 am* **Do hemifield representations co-opt ocular dominance column structure in achiasma?** Cheryl A. Olman[1](caolman@umn.edu), Pinglei Bao[2], Stephen A. Engel[1], Andrea N. Grant[3], Chris Purington[4], Cheng Qiu[1], Michael-Paul Schallmo[1], Bosco S. Tjan[2]; [1]Department of Psychology, University of Minnesota, [2]Department of Psychology, University of Southern California, [3]Department of Neuroscience, University of Minnesota, [4]Vision Science, University of California, Berkeley

In the absence of an optic chiasm, visual input to the right eye is represented in primary visual cortex (V1) in the right hemisphere, while visual input to the left eye activates only the left hemisphere. Retinotopic mapping reveals that left and right visual hemifield representations are overlaid in V1 in each hemisphere (Hoffman et al., 2012). To explain how overlapping hemifield representations in V1 do not impair vision, we tested the hypothesis (Victor et al., 2000) that visual projections from nasal and temporal retina create interdigitated left and right visual hemifield representations in V1, similar to the ocular dominance columns observed in control subjects. We used high-resolution fMRI at 7T to measure the spatial distribution of responses to left- and right-hemifield stimulation in one achiasmic subject. T2-weighted 2D Spin Echo images were acquired at 0.8 mm isotropic resolution, covering parafoveal regions of V1 (24 slices per 2 sec TR). The left eye was occluded while flickering checkerboards were presented to the right eye. Twelve sec presentations alternated between the left and right visual hemifield, separated by 12 sec mean field presentations. The subject performed a demanding orientation-discrimination task at fixation. A general linear model was used to estimate the responses of voxels in V1 to left- versus right-hemifield stimulation. The spatial distribution of voxels with preference for one hemifield or the other showed interdigitated clusters which densely packed V1 in the right hemisphere. The spatial distribution of hemifield-preference voxels in the achiasmic subject was comparable to the distribution of ocular-dominance voxels in a control subject, measured using standard techniques. These results are consistent with the hypothesis that visual hemifield representations interdigitate in achiasmic V1 following a similar developmental course to that of ocular dominance columns in controls.

Acknowledgement: NSF BCS-1255994, NIH R21 NS075525, P41 EB015894, P30 N5076408, P30 EY011374, S10 RR026783 and WM KECK Foundation

31.12, *8:30 am* **Transient monocular deprivation affects binocular rivalry and GABA concentrations in adult human visual cortex.** Claudia Lunghi[1,2](claudia.lunghi@in.cnr.it), Uzay Emir[3], Maria Concetta Morrone[4,5], David Charles Burr[1,2], Holly Bridge[3]; [1]Department of Neuroscience, University of Florence, Florence, Italy, [2]Institute of Neuroscience, CNR, Pisa, Italy, [3]Functional MRI of the Brain Centre, Nuffield Department of Clinical Neurosciences, University of Oxford, Oxford, United Kingdom, [4]Scientific Institute Stella Maris (IRCSS), Calambrone (Pisa), Italy, [5]Department of Translational Research on New Technologies in Medicine and Surgery, University of Pisa, Pisa, Italy

We have recently shown that the adult human visual system is more plastic than previously thought, as 150 minutes of monocular deprivation causes severe perceptual consequences on the dynamics of binocular rivalry (Lunghi, Burr, Morrone 2010), with the deprived eye dominating rivalrous perception for twice as long as the non-deprived eye. The duration of the effect depends on the stimulus tested, lasting for up to 180 minutes for equiluminant chromatic gratings (Lunghi, Burr, Morrone 2013). We hypothesized that this plasticity in adult cortex could result from a homeostatic boost of the contrast gain of the deprived-eye, which could be mediated by a decrease in intracortical inhibition. To test this hypothesis we measured metabolite concentrations from a 2x2x2cm voxel within the visual cortex (comprising the calcarine sulcus) in 12 adult human observers, using ultra-high field (7T) magnetic resonance spectroscopy before and after 150 min of monocular deprivation. Metabolite concentrations were quantified with LCModel using the unsuppressed water signal as reference. We coupled the MRS measurements with psychophysical testing of binocular rivalry between orthogonal red and blue gratings (SF 2cpd, contrast 50%, size 2°) presented separately to the eyes through anaglyph goggles. We found significant (paired t-test) modification of three metabolite concentrations following monocular deprivation: GABA (−11%), Glutamine (−11%), Taurine (+12%). Interestingly, only the variation in GABA showed a correlation with the perceptual effect of monocular deprivation on binocular rivalry, with the monocular deprivation induced decrease in GABA being significantly correlated with the increase in predominance of the deprived eye (Spearman's ranked correlation coefficient, rho = 0.86, $p<0.001$). Taken together these results suggest that one of the mechanisms mediating short-term monocular deprivation driven adult human visual cortical plasticity is a reduction in GABA-ergic inhibition in early visual cortices.

Acknowledgement: This research was supported by the Italian Ministry of Universities and Research (PRIN2009) and by ERC project "STANIB" (FP7 ERC) and the Royal Society University Research Fellowship UF0760314

31.13, *8:45 am* **Continuous Flash Suppression Modulates Cortical Activity in Early Visual Cortex** Shlomit Yuval-Greenberg[1](shlomitgr@tau.ac.il), David J. Heeger[2]; [1]School of Psychological Science and Sagol School of Neuroscience, Tel Aviv University, [2]Department of Psychology and Center for Neural Science, New York University

Purpose: A salient visual stimulus can be rendered invisible by presenting it to one eye while flashing a mask to the other eye. This procedure, called continuous flash suppression (CFS), has been proposed as an ideal way of studying awareness as it can make a stimulus imperceptible for extended periods of time without changing its physical properties. CFS has been extensively used to study visual awareness using behavioral measurements, functional magnetic resonance imaging (fMRI) , and electrophysiology. Previous studies reported robust suppression of activity in higher visual areas during CFS , but the role of primary visual cortex (V1) is controversial. Here, we resolve this controversy on the role of V1 in CFS, and offer an explanation of the computational processes underlying CFS. Methods: We measured activity in human V1 using fMRI while subjects viewed CFS stimuli composed of a mask and a target (low, medium or high contrast), presented to the same eye (always visible) or to different eyes (invisible for the low contrast). Each subject participated in multiple fMRI scanning sessions to ensure sufficient statistical power. Results: Functional MRI responses in early visual cortex were smaller when target and mask were in different eyes compared to the same eye, not only for the lowest contrast target rendered invisible by CFS, but also for higher contrast targets which were visible even when presented to the eye opposite the mask. Conclusions: Our results suggest that CFS is a form of perceptual masking, for which the presence of a mask suppresses activity evoked by the target , and that the suppression is stronger when mask and target are presented to different eyes. We propose that CFS impacts awareness by modulating the gain of neural responses to the target, at an early stage of visual processing, akin to reducing target contrast.

Acknowledgement: National Institutes of Health (R01-EY016752), the U.S.–Israeli Binational Science Foundation (2007224), the Weizmann–NYU Demonstration Fund in Neuroscience, the EU Marie Curie outgoing international Fellowship, the Weizmann Institute Advancing Women in Science Award.

31.14, *9:00 am* **Not all probes are created equal: Suppressed probes presented during binocular rivalry draw attention to the suppressed image** Brian A. Metzger[1,2](bmetzge2@illinois.edu), Kyle E. Mathewson[2], Evelina Tapia[1,2], Kathy A. Low[2], Ed L. Maclin[2], Monica Fabiani[1,2], Gabriele Gratton[1,2], Diane M. Beck[1,2]; [1]Department of Psychology, University of Illinois at Urbana-Champaign, [2]Beckman Institute for Advanced Science and Technology, University of Illinois at Urbana-Champaign

Binocular rivalry occurs when disparate images are shown simultaneously but separately to each eye. Perceptually dominant images reverse over time, with one image temporarily dominating perception while the other is suppressed. Probes presented to the suppressed eye are typically seen by participants and tend to cause perception to shift to the suppressed image. Here we ask why perception shifts to the suppressed eye. One possibility is that the probe draws attention to the suppressed eye/image. Prior fMRI research has implicated regions of the dorsal attention network in binocularly rivalry reversals more generally, and EEG research has shown specifically that suppressed-eye probes presented during binocular rivalry elicit larger ERP P3 responses, which have been associated with attentional orienting and allocation, compared to dominant-eye probes. We combine behavior, EEG, and fast event-related optical imag-

ing (EROS) to test the hypothesis that suppressed-eye probes are eliciting a shift in attention to the suppressed image. We find enhanced ERP N2 amplitude, which is thought to index attentional processing, followed by enhanced P3 amplitude for suppressed-eye probes compared to dominant-eye probes. Most notably, greater single-trial P3 amplitude evoked by suppressed-eye probes was correlated with faster subsequent switches to the suppressed image, suggesting the P3 may play a critical role in the switch. Furthermore, EROS data show greater activity for suppressed-eye probes compared to dominant eye-probes occurring in visual cortex and right intraparietal sulcus starting around 400 ms. followed by greater activity in right dorsolateral pre-frontal cortex starting around 700 ms., all of which occurs before the subsequent switch is complete. These later regions belong to the dorsal attention network, thus again implicating attention in the switch. Together, the behavioral, ERP, and EROS data indicate suppressed-eye probes are followed by classic neural markers of attention which may be critical to eliciting a reversal to the suppressed image.

Acknowledgement: NIH R01EY022605

31.15, *9:15 am* **Sensory memory of multi-stable displays: memory mechanisms are used to resolve ambiguity, not to stabilize perception** Alexander Pastukhov[1,2](pastukhov.alexander@gmail.com), Anna Lissner[1,2], Jochen Braun[1,2]; [1]Center for Behavioral Brain Sciences, Magdeburg, Germany, [2]Otto-von-Guericke Universität, Magdeburg, Germany

Multi-stable displays are ambiguous visual displays that have several comparably plausible interpretations. When presented continuously, their appearance reverses spontaneously from time to time. When presented intermittently (blank intervals >1 s), the appearance stabilizes, revealing the existence of an implicit visual memory ("sensory memory") for multi-stable appearance. What function does this "sensory memory" subserve, if any? Typically, it is assumed that its function is to ensure continuity of vision during interruptions ("stabilization of perception" hypothesis). We propose an alternative hypothesis: Memory mechanisms are transiently engaged to accumulate sensory evidence and resolve perception of challenging visual displays ("resolution of ambiguity" hypothesis). In this case, an implicit visual memory trace is a mere epiphenomenon left by an earlier interaction between perception and memory. These two hypotheses make different predictions for the contents of visual memory: "Stabilization" predicts that it should hold the most recent appearance of a display, whereas "resolution" predicts that it should hold the initial appearance when the perception was established (shortly after the stimulus onset). To distinguish between these possibilities, we used a rotationally asymmetric structure-from-motion (SFM) object, the configuration (and dominant perceptual appearance) of which changed continuously during viewing episodes (1000 ms duration). After a blank interval (1000 ms duration), we presented an ambiguous probe display, at an orientation that corresponded to one of the configurations viewed earlier. We used selective adaptation procedure [Pastukhov, Füllekrug, & Braun (2013) AP&P, 75(6)] to determine the contents of the sensory memory and to infer the time instant when it was induced. We find that memory contents corresponds to perceptual state of SFM object at ~120 ms after onset. We conclude that lingering visual memory trace reflects an earlier transient engagement of memory mechanisms that were recruited to accumulate sensory evidence, assisting sensory regions in resolving perception of challenging (ambiguous) displays.

Acknowledgement: The authors were supported by the BMBF Bernstein Network and the State of Saxony-Anhalt.

31.16, *9:30 am* **Interocular competition at higher levels of motion processing** Vivian Holten[1](v.holten@uu.nl), Sjoerd M. Stuit[1], Maarten J. van der Smagt[1], Stella F. Donker[1], Frans A.J. Verstraten[1,2]; [1]Experimental Psychology Division, Helmholtz Institute, Utrecht University, The Netherlands, [2]School of Psychology, The University of Sydney, Australia

Binocular rivalry is thought to occur at multiple stages along the visual processing hierarchy. Although monocular channels in primary visual cortex have been suggested to play an important role, recent studies have hinted at monocular information being available to higher-level visual (motion) areas. These areas, such as the medial superior temporal area (MST), are involved in the processing of radial optic flow. It is known that cells in these areas are selectively tuned to either expansion or contraction, while areas earlier in the visual hierarchy cannot distinguish between these two directions. Previous studies have shown that MST cells tuned to expansion outnumber those tuned to contraction. If monocular information reaches higher-level visual areas, one might expect that these tuning differences play a role in binocular rivalry. Here we question whether the time it takes to reach awareness differs between expanding and contracting optic flow. We used breaking continuous flash suppression to measure the duration until expanding or contracting optic flow broke suppression. Observers viewed the stimuli (3.6° radius) through a mirror stereoscope mounted on a chin rest. A white frame and a noise pattern (subtending 4.9° x 4.9°) surrounded the stimuli to facilitate binocular fusion. During the experiment, one eye viewed a mask (refresh rate 10Hz), which was created by filtering pink (1/f) noise using a low-pass filter ($\sigma = 1.5$), while the other eye viewed an either expanding or contracting radial optic flow pattern with a quadratic speed gradient (speed 2.7 deg/s). Observers pressed one of the two response keys to discriminate the optic flow direction as soon as possible within 6-second trials. The results show that expanding optic flow breaks suppression faster than contracting optic flow. These results may, for instance, reflect the larger prevalence of cells tuned to expansion in MST, suggesting monocular contributions to higher-level motion processing.

Visual memory

Sunday, May 18, 8:15 - 9:45 am
Talk Session, Talk Room 2
Moderator: Christian Olivers

31.21, *8:15 am* **Human Visual Memory in the Past and Future: Predicting Individual Recall using Eye-Movements** Zoya Bylinskii[1,2](zoya@mit.edu), Phillip Isola[3], Antonio Torralba[1,2], Aude Oliva[1]; [1]Computer Science and Artificial Intelligence Laboratory, MIT, [2]Department of Electrical Engineering and Computer Science, MIT, [3]Department of Brain and Cognitive Sciences, MIT

What can eye movements tell us about human visual memory? Recent work has shown that image memorability is highly consistent across observers, allowing average memory effects to be studied (Isola 2011). The focus of our work is predicting memory performances at the level of the individual subject on a trial-by-trial basis, by analyzing the oculomotor behavior of an observer viewing images. Can we use an individual's eye movements to predict whether (1) she will recognize a specific image later, and (2) infer whether she has seen an image before? Fixations from 20 observers were recorded as they watched 1000 images for 2 seconds each (of which ~200 were repeated once). We compare the similarity of an individual's eye movements to fixation patterns typical at encoding (first presentation) as well as to those typical during correct recall (second presentation). Using logistic regression, we map these similarity measurements to memory predictions. We are able to (1) predict with an accuracy of 62.52% (SD: 2.1%, chance: 50%) whether an individual will remember a particular image in the future, and (2) infer with an accuracy of 71.65% (SD: 1.7%) whether an individual has recognized an image seen in the past. Additionally, we do significantly better by considering a subset of images, sorted by how different the typical encoding and recall patterns are for those images. For cases where we don't have a population of individuals to provide the typical fixation locations on an image, our fully computational approach achieves similar performances on tasks (1) and (2) by using image content to simulate fixation maps. Our results suggest that at the level of the individual subject, eye movements can serve as an accurate tool for predicting long-term visual memory performances along both directions of the time axis: past and future.

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31.22, *8:30 am* **Environment sensitivity in hierarchical representations** Timothy Lew[1](tim.f.lew@gmail.com), Edward Vul[1]; [1]University of California, San Diego

People seem to compute the ensemble statistics of objects and use this information to support the recall of individual objects in visual short-term memory. However, the appropriate grouping of objects into ensembles is not always obvious, and people may need to infer different hierarchical organizations of the objects. These different organizations should determine how ensemble information influences object recall. We tested whether objects' hierarchical structure influences visual short-term memory recall and assessed the encoding scheme people use to represent objects in a hierarchical structure. To address these questions, we asked subjects to recall the locations of objects arranged in different spatial clustering structures. Objects in the same cluster were recalled with similar displacement errors, suggesting that the hierarchical structure induced correlated errors. Furthermore, objects arranged into fewer clusters containing more objects were recalled more accurately. We considered three accounts of this improvement: (a) fewer misassociations of objects to locations, (b) more effective random guessing around cluster centers, and (c) more accurate encoding of object locations. Our analyses suggest that performance improved as objects were more densely clustered because guessing around the clus-

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ter centers decreased and object locations were recalled more accurately. One explanation for this pattern is that subjects represented the relative positions of objects using a log encoding. Such a scheme would allow more densely clustered objects to be recalled with greater fidelity. Consequently, we designed a model that represents the locations of objects relative to their clusters and recalls the relative positions with Weber noise on distance. We fit the model to subjects' responses and found for each clustering structure the model was able to accurately predict objects' bias towards clusters and the noise of object locations. Together, these results suggest that denser clustering allows more parsimonious encoding of the object hierarchy, preserving resources for encoding individual objects.

31.23, *8:45 am* **Shared visual memory resources for individuation and ensemble representation** Brandon Liverence[1](liverence@gmail.com), Steven Franconeri[1]; [1]Northwestern University

Two distinct kinds of information can be represented in visual short-term memory: precise representations of individual objects (individuation), and summaries/averages of multiple objects (ensemble representation). Prior studies have found that observers can accurately report average features (e.g., location or facial emotion) from sets of many items even when unable to recall the features of any individual item, suggesting that individuation and ensemble representation may be subserved by distinct processes, and perhaps also distinct memory resources. Here, we suggest that these modes of representation may instead rely upon a shared pool of memory resources, by demonstrating that the precision of individuation and ensemble representation are mutually interdependent: precise encoding of one type of information entails reduced precision in the other. In Study 1, observers briefly viewed three discs and were subsequently cued to report either a specific disc's location (Individuation task) or the centroid of all three discs (Ensemble task). On some trials, the discs were also connected by bars. We reasoned that connection should bias the visual system towards storing the centroid of the larger object that it creates, whereas in unconnected displays the bias should be towards representation of discrete individuals. As predicted, connection produced enhanced memory for the centroid and impaired memory for individual object locations (supported by a highly significant Connectedness-by-Task interaction). In Study 2, we tested whether observers could switch between individuation and ensemble representation when given pre-cues that predicted (with 80% validity) the subsequent test type. Valid pre-cues led to enhanced accuracy on both tasks, suggesting that observers can effectively control the preferred encoding. Collectively, these findings suggest that individuation and ensemble representation compete with one another, and that the visual system can flexibly switch between these modes as a way of efficiently managing its limited memory resources.

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31.24, *9:00 am* **In competition for the attentional template: Only a single item in visual working memory can guide attention** Christian Olivers[1](c.n.l.olivers@vu.nl), Dirk van Moorselaar[1], Jan Theeuwes[1]; [1]Department of Cognitive Psychology, VU Amsterdam

Recent studies have revealed that the deployment of visual attention can be biased by the content of visual working memory (VWM). However, stored visual memories do not always interact with attention. This has led to a model which proposes a functional division within VWM, between a single active template that interacts with perception and multiple accessory memory representations that do not. The present study investigated whether memory-based attentional guidance is indeed limited to a single representation or whether multiple items in memory are able to bias attention. Participants performed a visual search task while maintaining a variable number of colors in VWM. We observed increased attentional capture by memory-related distractors when VWM was filled with a single item. However, memory-related capture disappeared completely for memory loads beyond a single item. The absence of memory-related capture at higher VWM loads was not dependent on individual VWM capacity, nor was it attributable to weaker encoding, forgetting, or reduced precision of memory representations. When analyses were limited to those trials on which participants had a relatively precise memory, there was still no sign of attentional guidance at higher loads. However, when observers were required to remember multiple items, but were then cued towards a specific memory item after encoding, interference with search returned for the cued item. Uncued items did not interfere with search even though the task still required them to be remembered. These results are consistent with a multilayer model of VWM, which makes a distinction between representations that interact with perception and those that do not. Only a single item can have access to the visual input, and cueing an item, or simply being the single item in VWM, automatically causes it to acquire this status of attentional template.

31.25, *9:15 am* **On the dynamic nature of VWM: Separate limits for the storage and manipulation of information** Hrag Pailian[1](hrag.pailian@gmail.com), Melissa Libertus[2], Lisa Feigenson[1], Justin Halberda[1]; [1]Psychological and Brain Sciences, The Johns Hopkins University, [2]Psychology, University of Pittsburgh

Based on the large number of objects in any visual scene, and our ever-changing goals, it is ecologically natural for humans to dynamically adjust which information and items are stored in Visual Working Memory (VWM) across views. This means that effectively using VWM in context requires observers to e.g., load and purge items from VWM, switch attention to new items, compare and make decisions, and so forth. Here, we explore these dynamic aspects of VWM, and we identify independent limits on the dynamic manipulation of information in VWM - distinct from VWM storage limits (K). In contrast to the more typical One-Shot change-detection task that has been used to estimate VWM storage capacity (K), we developed a Flicker method that separately estimates storage and dynamic processes. Participants viewed alternating displays of many colored squares separated by a blank where one square changed colour on each iteration. To find the changing target, participants had to not only store items, but had to employ dynamic processes, such as loading and purging items from memory, switching attention, making decisions, etc. Response times were transformed into an estimate of storage capacity (K), as well as an additional component representing these dynamic processes (Δ). In a series of experiments, we demonstrate that Flicker K estimates are more reliable than One-Shot K estimates (Exps 1-6), that Flicker K correlates with One-Shot K, while Flicker Δ remains independent (Exp 7), and that Flicker K and Δ increase (i.e., improve) during the early elementary school years (Exps 8-9). Our approach and results place a renewed focus on the dynamic requirements of using VWM in context, and demonstrate the importance of incorporating both storage (K) and manipulation (Δ) in models of VWM.

31.26, *9:30 am* **The more you try to remember, the faster you forget: load-dependent forgetting and mnemonic overreaching** Jordan W. Suchow[1](suchow@fas.harvard.edu), George A. Alvarez[1]; [1]Department of Psychology, Harvard University

Visual memory enables a viewer to hold in mind details of objects, textures, faces, and scenes. After initial exposure to an image, however, memory rapidly degrades. To gain insight into this process, and to better understand memory maintenance, we examined whether degradation depends on the amount of information being maintained. We collected high-quality forgetting functions, testing a five-hundredfold range of durations (0.03–16 s) and a twelvefold range of loads (1–12 objects) in a working memory task for object color. We found that the rate of forgetting depends on the total amount of information held in mind, with lone memories lasting longest (estimated mean lifetime of 157 s) and higher loads leading to progressively shorter lifetimes (correlation between load and lifetime, r = 0.98). Load-dependent forgetting implies that simultaneously-held memories interact during maintenance, perhaps because they compete for a shared commodity such as "slots", "resources", or time. In some cases, the lines of the forgetting functions for each load cross. At short durations, presenting a greater number of objects causes more to be remembered (e.g., at 2 s, more objects are remembered at load 8 than at 2). At long durations, however, the opposite is often true — presenting a greater number of objects causes fewer to be remembered (e.g., at 16 s, fewer are remembered at load 8 than at 2). The presence of crossovers suggests flawed strategy choice or execution by the participants, who presumably control how much to encode and maintain. Like a bodybuilder who herniates a disk by straining to lift too heavy a weight, our participants performed worse by encoding or maintaining too much — they overreached. Together, these results suggest that the process of active maintenance is dynamic and depends on how much information is being held in mind.

Acknowledgement: NSF CAREER BCS-0953730 to G.A.A.

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Spatial vision: Mechanisms, methods, models and time

Sunday, May 18, 10:45 am - 12:30 pm
Talk Session, Talk Room 1
Moderator: Richard Murray

32.11, *10:45 am* **A classification-image-like method reveals strategies in 2afc tasks**

Richard Murray[1](rfm@yorku.ca), Lisa Pritchett[1]; [1]Department of Psychology and Centre for Vision Research, York University

Despite decades of research, there is still uncertainty about how observers make even the simplest visual judgements, such as 2AFC decisions. Here we demonstrate a new method of using classification images to calculate “proxy decision variables” that estimate an observer’s decision variables on individual trials. This provides a new way of investigating decision strategies. In Experiment 1, nine observers viewed two disks in Gaussian noise, to the left and right of fixation, and judged which had a contrast increment. The contrast increment was set to each observer’s 70% threshold. On each trial we calculated the cross-correlation of the observer’s classification image with the two disks, providing proxy decision variables. Using 10,000 such trials per observer we mapped the observer’s decision space: we plotted the probability of the observer choosing the right-hand disk as a function of the values of the two decision variables. We tested the hypotheses that observers base their 2AFC decisions on (a) the difference between the two decision variables, (b) independent yes-no decisions on the two decision variables, or (c) just one of the decision variables. We found that all observers’ decision spaces had a triangular guessing region, which is not predicted by any of the above models. However, this finding is consistent with model (a) plus intrinsic uncertainty. We conclude that the classic difference model favoured by detection theory is a valid model of 2AFC decisions. In Experiment 2, four observers discriminated between black and white Gaussian disks at fixation, and the two stimulus intervals were separated in time (1000 ms) rather than space. Again observers’ decision spaces supported the difference model. We discuss how proxy decision variables can be used to test a wide range of additional signal detection models in domains such as cue combination and visual search.

Acknowledgement: NSERC

32.12, *11:00 am* **A kindler, gentler adaptive psychophysical procedure**

Daniel Coates[1,2](daniel.coates@berkeley.edu), Susana Chung[1,2]; [1]Vision Science Graduate Group, University of California, Berkeley, [2]School of Optometry, University of California, Berkeley

Despite disadvantages such as inefficient use of trials, the method of constant stimuli remains popular in psychophysical measurement. It is simpler to implement, less taxing on observers, and more immune to lapse errors than adaptive techniques such as staircases or QUEST. The challenge then is to find an optimal set of stimulus levels for each subject in order to estimate a full psychometric function (PF). Efficiency is important when limited trials are available due to time constraints or subject fatigue. We evaluated a hybrid procedure where the testing levels are specified in terms of the mean and spread of a parameterized PF. With only the minimum and maximum stimulus levels detailed beforehand, the PF parameters are estimated online during the testing procedure and guide stimulus placement. Unlike other adaptive methods that eventually repeat testing near the subject’s threshold, stimuli are chosen randomly from the specified points on the PF, mitigating expectation bias and subject fatigue. First, using Monte Carlo simulations, we explored optimal stimulus placement for known PFs. We validated previous literature showing that parameters can be estimated equally well with 2-5 carefully placed stimulus locations, with some variation based on the total number of trials. Approximately 100 trials were required to ensure that 95% of the simulations were within 5% of the veridical parameter values. Surprisingly, when the PF was initially unknown and progressively estimated during a simulated run, 100-150 trials were sufficient to reliably converge to the veridical parameter values. Experiments with human observers, including some with significant variability, confirmed that parameter estimation was less accurate when trials remained near subject thresholds, versus those that spread more broadly across the PF. In summary, this method provides a compromise between the flexibility and optimality of adaptive procedures and the simplicity and robustness of the method of constant stimuli.

Acknowledgement: NIH R01-EY012810

32.13, *11:15 am* **Symmetry: Less than meets the eye**

Deborah Apthorp[1,2](deborah.apthorp@anu.edu.au), Jason Bell[3]; [1]Research School of Psychology, College of Medicine, Biology & Environment, Australian National University, [2]School of Psychology, Faculty of Social Sciences, University of Wollongong, [3]School of Psychology, Faculty of Science, University of Western Australia

Introduction: Symmetry is a ubiquitous feature in visual scenes and human observers are highly sensitive to it. Does the presence of symmetry bias our estimate of scene content? We consider this question in the context of numerosity judgments. Recently, it has been suggested that a simple model using the relative response of mechanisms tuned to low and high spatial frequencies can predict systematic errors in both number and density estimations by human observers (Dakin et al., PNAS 2011). Here we ask whether these estimations can also be biased by the higher-order statistics of the displays. Method: We asked observers to estimate the relative number of elements in symmetrical compared to asymmetrical dot displays, using a 2-interval, forced-choice paradigm with adaptive staircases (QUEST). Reference displays contained 50, 100 or 200 dots, and comparison displays were adjusted to obtain the point of subjective equality (PSE). To assess whether the effect was due to perceived global structure within the symmetric display, we also tested with concentric Glass patterns (which had global structure but not symmetry) compared to randomly-oriented Glass patterns. Results: Symmetrical displays were consistently judged as less numerous than asymmetrical displays, and this effect persisted across different dot numbers, dot densities and axes of symmetry. Symmetrical displays required approximately 10% more elements to appear as numerous as asymmetrical displays, although the effect was smaller at higher dot numbers and at oblique axes of symmetry. For Glass patterns, the effect was greatly reduced, and was abolished at higher element numbers, suggesting the bias could not be attributed solely to the perceived structure in a symmetric pattern. We discuss the results in terms of current models of number and density judgments.

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32.14, *11:30 am* **Non-orthogonal channels for relative numerosity and contrast detection**

Michael Morgan[1](m.morgan@city.ac.uk), Donald MacLeod[2]; [1]Max-Planck Institute for Neurological Research, Cologne, Germany, [2]Department of Psychology, UCSD, USA

Non-orthogonal channels for relative numerosity and contrast detection Previous studies with spatially-sampled luminance gratings have shown reciprocity between luminance and dot density for detection1 and accurate interpolation between samples for vernier acuity2. We extended these investigations to contrast and numerosity-modulated sine-wave gratings using a 70 x 70 sampling grid of Gaussian-shaped dots that were randomly assigned to be increments or decrements on a mean-luminance background, with a contrast that was modulated sinusoidally in one dimension over the pattern. Numerosity was modulated either by one-dimensional sinusoidal modulation of dot probability (present/absent) or by one-dimensional modulation of nearest-neighbour dot separation1. Contrast and numerosity were modulated either separately in different blocks of trials, or together. If together, contrast and numerosity modulations could be either in register or in opposite spatial phase. The axis of spatial modulation was either the clockwise or anticlockwise diagonal; the observer’s task was report which. Threshold modulation depth was measured by an adaptive procedure. Strong phase-dependent additivity between contrast and numerosity was found, suggestive of a mechanism detecting contrast energy modulation indifferently between numerosity and contrast. The implications for models of approxiate numerosity perception3 will be discussed. (1) Mulligan, J. B. & MacLeod, D. I. Reciprocity between luminance and dot density in the perception of brightness. Vision Res 28, 503-519 (1988). (2) Morgan, M. J. & Watt, R. J. Mechanisms of interpolation in human spatial vision. Nature 299, 553-555 (1982). (3) Burr, D. & Ross, J. A visual sense of number. Curr Biol 18, 425-428,

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32.15, *11:45 am* **Encoding space in time: a model of human contrast sensitivity in the presence of fixational eye movements**

Michele Rucci[1,2](mrucci@bu.edu), Jonathan Victor[3], Xutao Kuang[1]; [1]Department of Psychology, Boston University, [2]Graduate Program in Neuroscience, Boston University, [3]3Brain and Mind Research Institute, Weill Cornell Medical College

The contrast sensitivity function is perhaps the most studied function in spatial vision, and the mechanisms underlying its shape have been extensively debated. These mechanisms are commonly assumed to be neural.

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However, small eye movements continually occur during fixation. We have recently shown that fixational eye movements transform the spatial power of the stimulus into temporal modulations in a very specific manner (Kuang et al., 2012). Here we examine the possible influences of this space-time reformatting on human contrast sensitivity. We modeled the responses of P and M neurons in the macaque retina and lateral geniculate nucleus using rectified linear filters. Models were designed to match the neural contrast sensitivity functions recorded by neurophysiological experiments in the absence of eye movements. These functions deviate significantly from behavioral measurements of contrast sensitivity: they peak at lower spatial frequencies and do not exhibit the strong low-frequency suppression present in human contrast sensitivity. Models were exposed to the spatiotemporal input stimuli experienced by human observers during measurements of contrast sensitivity, the input signal resulting from viewing the stimulus in the continual presence of microscopic eye movements. Eye movements were recorded by means of a Dual Purkinje Image eyetracker, a device with high spatial and temporal resolution. Our model closely predicts psychophysical measurements of human contrast sensitivity measured during normal fixation over a broad range of spatial and temporal frequencies. Furthermore, our model also predicts the contrast sensitivity function measured under retinal stabilization, a condition in which some degree of residual motion persists. These results give further support to the proposal that fixational eye movements act as a critical pre-processing stage in the representation of visual information and suggest an important role of these movements in shaping human contrast sensitivity.

Acknowledgement: Supported by NIH EY18363, NSF BCS-1127216 to MR, and NIH EY07977 and EY09314 to JDV

32.16, *12:00 pm* **The Radial Bias Is Not Necessary For Orientation Decoding** Michael Pratte[1](prattems@gmail.com), Jocelyn Sy[1], Frank Tong[1]; [1]Dept. of Psychology, Vanderbilt University

Multivariate pattern classification can be used to decode the orientation of a viewed grating from fMRI signals in the human visual cortex. We have speculated that this orientation signal results in part from the fine-scale columnar structure of orientation-tuned cells. In addition, it has been known since the earliest demonstration of orientation decoding that other, more coarse-scale orientation signals might also contribute to successful decoding, such as the retinotopic bias for orientations radiating outward from the fovea found in the retina, LGN, and V1. More recently, Freeman, Brouwer, Heeger and Merriam (2011) made the stronger claim that this radial bias is completely necessary for orientation decoding. They claimed that if this bias is mathematically removed, then orientation can no longer be decoded. However, their study relied on a temporal phase-encoding procedure in which a grating was rotated through the orientation domain over time. With this design, voxel responses depend on both orientation selectivity and on temporal characteristics of the hemodynamic response, and we show that conflating these sources may lead to erroneous conclusions. We successfully replicate Freeman et al.'s findings with a fast 24-s rotation period, but find persisting orientation signals with a slower rotation period that minimizes temporal blurring of the BOLD response. In addition, we show that simply blurring the edges of the wedge stimulus used to map the radial bias reduces temporal artifacts, and again reveals a persistence of orientation signals even at the faster rotation period. Our results imply that Freeman et al.'s conclusions were in fact due to the confounding of orientation signals and hemodynamic factors, and consequently depended on very particular stimulus conditions. When we take this confound into consideration, we find robust evidence of orientation information in fMRI signals in the human visual cortex that do not depend on the radial bias.

32.17, *12:15 pm* **Layer-specific fMRI signals in the human LGN – An investigation of magnocellular and parvocellular pathways in normal subjects and glaucoma patients** peng zhang[1](zhang870@umn.edu), wen wen[2], xinghuai sun[2], sheng he[1,3]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Biophysics, Chinese Academy of Sciences, Beijing, 100101, China, [2]Department of Ophthalmology, Eye and ENT Hospital, Fudan University, Shanghai, 200031, China, [3]Department of Psychology, University of Minnesota, Minneapolis, Minnesota, 55414, USA

The human visual system consists of two functionally and anatomically distinct parallel pathways, namely the magnocellular (M) and parvocellular (P) pathways, which are particularly well represented by the segregated M and P layers of the lateral geniculate nucleus (LGN) of the thalamus. With functional MRI, we were able to reliably localize the M and P layers of the human LGN, using the M and P stimuli designed to preferentially activate the magnocellular or the parvocellular neurons. The topography of the identified M and P layers are in good agreement with the anatomy of the human LGN, and the fMRI measured response properties of the M and P layers are highly consistent with the LGN physiology. Applying this layer-specific fMRI technique, we tested the longstanding yet controversial hypothesis of large cell loss in glaucoma: whether neural damage from early-stage glaucoma is selective to the magnocellular cells. Compared to normal controls, glaucoma patients showed a significant reduction of LGN responses to the M stimulus but not to the P stimulus, and also this selective reduction of response to the M stimulus was found only in the M layers but not in the P layers of the LGN. A selective loss of fMRI response to the M stimulus was also found in the superficial layer of superior colliculus (SC), but not in the cortical visual areas. These results show that fMRI is capable of resolving layer specific signals from subcortical nuclei, and a selective functional loss from early glaucoma can be found in the magnocellular layers. The layer-specific fMRI approach thus proved to be a powerful tool to study the neural mechanisms of parallel pathways in the human visual system.

Perceptual learning

Sunday, May 18, 10:45 am - 12:30 pm
Talk Session, Talk Room 2
Moderator: Mark Wexler

32.21, *10:45 am* **Statistical regularities shape object perception** Sumeyye Cakal[1](sumeyyecakal@yahoo.com), Jiaying Zhao[1,2]; [1]Department of Psychology, University of British Columbia, [2]Institute for Resources, Environment and Sustainability, University of British Columbia

The environment contains widespread regularities in terms of how objects co-occur in space and over time. How regularities alter the perception of individual objects is largely unexplored. In Experiment 1, we examined how learning spatial co-occurrences of individual objects alters the perception of the spatial location of these objects. Observers were exposed to arrays of colored circles. In the 'structured' condition, each array contained four color pairs which were arranged in fixed spatial configurations (e.g., red always appears to the left of blue). In the 'random' condition, the same configuration was maintained, but now one circle in the pair was shuffled, while the other circle remained in the same position (e.g., red appears to the left of blue, brown, or purple). After exposure, one circle was briefly presented on the screen and observers indicated the location of the circle. We found that the location of the circle was perceived to be closer to the location of its partner in the pair in the structured condition than in the random condition. To generalize this finding, in Experiment 2, we examined how regularities in line orientations alter the perception of these orientations. Observers were exposed to a sequence of lines. In the structured condition, the sequence consisted of three pairs of orientations, and in the random condition, the orientations were presented in a random order. We found that the orientation of the line was perceived to be more similar to the orientation of its partner in the pair in the structured condition than in the random condition. These results demonstrate that the representation of a stimulus is biased toward to that of another if the stimuli reliably co-occur. This suggests that incidental learning of object co-occurrences can shape the perception of individual objects, revealing fundamental ways in which learning can guide perception.

32.22, *11:00 am* **The neural changes associated particularly with perceptual learning trained with reward are not essential to perceptual learning in general** Dongho Kim[1](dongho_kim@brown.edu), Yuka Sasaki[1], Takeo Watanabe[1]; [1]Cognitive, Linguistic & Psychological Sciences, Brown University

Reward plays an important role in visual perceptual learning (VPL, Seitz, Kim, & Watanabe, 2009). Does this mean that the neural changes particularly associated with VPL trained with reward is essential to VPL in general (Law & Gold, 2009)? To address this question, 8 subjects were trained on the texture discrimination task (TDT, Karni & sagi, 1991) for 14 daily training sessions. Subjects were asked to perform the TDT during BOLD measurements at 3 different stages: pre-training, and after the 1st and 14th training sessions. All subjects were asked to refrain from eating or drinking for 5 hours before each training and measurement sessions. Trial-based water reward was given to subjects for a correct response. Diffusion tensor imaging (DTI) was also performed immediately after each scan of the BOLD measurement. In addition, a different group of 11 subjects participated in a control experiment whose procedure was identical to that of the main experiment except that no reward was given to the subjects. Results showed that the caudate, thalamus, amygdala, and hippocampus from the trained hemisphere showed significant BOLD activation increases at the second BOLD measurement stage. However, BOLD activations in

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the caudate and thalamus significantly dropped at the 3rd stage, whereas the hippocampus and amygdala showed the sustained BOLD activations at the 3rd stage. DTI results showed that fractional anisotropy of the cingulum-cingulate gyrus bundle, which connects the basal ganglia and limbic system through the thalamus significantly decreased at the 2nd DTI stage but increased again in the 3rd DTI, whereas the mean length of the bundle decreased over the stages, suggesting the axonal rewiring in these regions. In the control experiment, no such change in any of the above-mentioned areas was observed. These results indicate that neural changes in reward processing are not essential to perceptual learning in general.

Acknowledgement: NIH R01 EY015980 and Honda Research Institute Japan

32.23, *11:15 am* **Object Representations in Human Visual Cortex are Flexible: an Associative Learning study.** Mehdi Senoussi[1](senoussi.m@gmail.com), Isabelle Berry[2, 3], Rufin VanRullen[1], Leila Reddy[1]; [1]Centre de Recherche Cerveau et Cognition (CerCo), CNRS UMR 5549, Université Paul Sabatier, Toulouse, France, [2]Inserm Imagerie cérébrale et handicaps neurologiques UMR 825 F-31059 Toulouse, France, [3]Centre Hospitalier Universitaire de Toulouse Pôle Neurosciences CHU Purpan, Place du Dr Baylac, F-31059 Toulouse Cedex 9, France

Creating associations between different objects is a critical way in which we interact with our environment. Forming new associations relies on the medial temporal lobe, while their longer-term storage is mediated by cortex. However, the large-scale neural changes accompanying these newly formed associations are not fully understood. In this study we investigated whether the fMRI multi-voxel representations of associated object categories become more similar to each other as a result of creating arbitrary new associations between them. Nine human subjects were scanned in a 3T scanner before and after they learned arbitrary associations between pairs of different object categories (faces, houses, cars, chairs). The learning procedure consisted of 20-minute sessions over 15 days during which subjects were required to learn arbitrary associations between 10 different exemplars of these categories (e.g., each face was associated with a car/each house with a chair). During the fMRI sessions before and after learning, subjects were presented with these categories in a blocked design and were required to perform a one-back task on the images. To evaluate how object representations change as a result of learning we used the searchlight method of analysis in which a classifier was trained to discriminate between categories A and B, and tested on discriminating C versus D, where A-C and B-D indicate the category pairs (arbitrarily) associated during learning. Our results show that cross-classification performance was at chance levels before learning (because the association was arbitrary, and the category assignment counterbalanced across subjects), but that after learning different regions of the occipital and temporal lobes displayed increased performance. Overall subjects and all voxels the average increase (2%) was highly significant (p<10-6). These results thus suggest that the representations of associated categories in these regions are not static, but become more similar to each other as a result of learning.

Acknowledgement: Agence Nationale de la Recherche, Institut des Sciences Cognitives de Toulouse

32.24, *11:30 am* **Biases in multistable displays as dynamic state variables** Mark Wexler[1,2](mark.wexler@parisdescartes.fr), Pascal Mamassian[1,3]; [1]CNRS, [2]Université Paris Descartes, [3]Ecole Normale Supérieure

Observers show idiosyncratic biases in the perception of multistable stimuli, such as in the perception of tilt from structure-from-motion stimuli and in the perception of depth order in motion transparency. By measuring biases across a sampling of all surface tilts and motion directions, we show the perception of these stimuli in a vast majority of observers is governed by internal state variables, one for preferred tilt and one for preferred motion direction. These state variables are directions in the image plane. The predominant pattern is that only tilts within 90 deg of the preferred tilt are perceived; in the motion domain, motions with direction within 90 deg of the preferred motion direction are perceived closer to the observer in transparency displays (see Mamassian & Wallace, JOV 2010, for older results on the transparency display). We measured population distributions of these state variables in nearly a thousand subjects, and have found anisotropic distributions with peaks in the cardinal directions and suprising asymmetries, as well as lack of any correlation between the shape and motion variables. The state variables can be perturbed using carefully chosen unambiguous stimuli, showing attraction to the unambiguous direction, but then systematically relax to their initial values over tens of seconds. Change in the variables does occur naturally, and seems to be driven by internal dynamics rather than external stimulation. Over a two-week period, the median change in the state variables is about 10-15 deg; over one year, it's about 20-30 deg. When measured every day over extended periods, the dynamic behavior of the state variables shows a wide variety of behaviors: periods of stability, sudden transitions, rapid there-and-back excursions, oscillations between discrete values, and slow drifts. These unsuspectedly rich patterns of behavior open a window onto the internal functioning of the visual system.

32.25, *11:45 am* **Four days of visual contrast adaptation: effects on perceived contrast grow monotonically while effects on orientation rise then fall.** Elizabeth Fast[1](fastx055@umn.edu), Koen Haak[2], Min Bao[3], Stephen A. Engel[1]; [1]Department of Psychology, University of Minnesota, [2]Donders Centre for Cognitive Neuroimaging, Donders Institute for Brain, Cognition and Behaviour, Radboud University Nijmegen, [3]Institute of Psychology, Chinese Academy of Sciences

The visual system continuously adapts to its environment. In contrast adaptation, exposure to high contrast patterns reduces the apparent contrast of similar patterns and shifts apparent orientation away from the adapter (the tilt-aftereffect). Most studies to date have examined only short periods of adaptation, generally a few minutes, so how perception changes over longer adapting periods remains unknown. Here we measured the effects of four days of adaptation to reduced contrast, which has similar effects to classic contrast adaptation, but in the opposite direction. Subjects wore a camera, whose video was filtered in real time and viewed on a head-mounted display. Filtering removed 85% of vertical energy from the images. Twelve subjects wore the display during their waking hours, and were blindfolded during rest breaks and at night. Perception was tested 4 times daily: To measure apparent contrast, subjects adjusted a horizontal grating patch to match the apparent contrast of a 5% vertical test. To measure the tilt-aftereffect, subjects adjusted the orientations of two 45 deg gratings, superimposed to make a plaid, until the plaid's intersections appeared square. The average perceived contrast of the 5% test rose during the first day to ~7.5%, and then continued to grow smoothly during the second through fourth days to end at ~8.5%, with a reliable linear trend (p <0.05). The tilt-aftereffect showed a different pattern; it rose to ~1.5 deg on the first day, and to ~2 deg on the second day, but fell on the third and fourth days to end near 1 deg, with a reliable quadratic trend (p <0.05). These results suggest that over many days of adaptation the visual system maintains effects that render the appearance of the world more natural, while correcting for effects, such as the tilt-aftereffect, that distort its appearance.

Acknowledgement: NSF BCS 1028584

32.26, *12:00 pm* **Adaptation** to patch-wise complementary video reduces perceptual ocular dominance Bo Dong[1](dongb283@gmail.com), Yi Jiang[1], Stephen Engel[2], Min Bao[1]; [1]Institute of Psychology, Chinese Academy of Sciences, [2]Department of Psychology, University of Minnesota

Recent studies have revealed residual perceptual ocular dominance plasticity in adult humans. Here we introduce a novel method to reduce interocular imbalance through long-term adaptation. Subjects viewed the world through an "altered reality" system comprised of a head mounted video camera that fed into an image-processing computer that in turn drove a head-mounted display. Video images in each eye were divided into a 9x16 grid of square cells. Half of the cells were rendered a uniform mean color, while in the rest of the cells the original content remained unaltered. The layout of uniform cells was randomized and updated every 30 sec on average. Importantly, layouts in the two eyes were complementary, such that uniform cells in one eye corresponded to intact image patches in the other. Viewing this complementary patchwork video, subjects were able to interact with the world while being required to make use of the visual inputs to both eyes cooperatively in order to see a complete image. Seven subjects adapted to the patchwork displays for 3 hours, and eye dominance was measured using binocular rivalry before and following adaptation. Interocular imbalance was reduced following adaptation, as indexed by the proportion of stable percepts in rivalry that corresponded to each eye. The dominance of the stronger eye fell from 62.7% in the pretest to 56.0% in the post-test (averaged across three tests given within one hour after adaptation) and remained reduced 24 hours (53.4%) and three days later (57.2%, all ps <0.05). Viewing the world without patchwork for 3 hours produced no reliable effects. Our results suggest that long-term adaptation to a visual world that forces binocular integration can produce long-lasting balancing of perceptual weights given to the inputs from the two eyes, providing a promising approach for treatment of disorders such as amblyopia.

Acknowledgement: Supported by the Key Research Program of the Chinese Academy of Sciences (KSZD-EW-TZ-003)

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32.27, *12:15 pm* **A unifying mechanism underlying adaptation and perceptual learning** Kyle McDermott[1](kyle.c.mcdermott@gmail.com), Pascal Mamassian[1]; [1]Laboratoire des Systèmes Perceptifs (CNRS) , Ecole Normale Supérieure

Repeated stimulus presentations can lead to dramatic changes in the perception of subsequent stimuli. Two such phenomena are biased perception (after-effects) due to adaptation and increased sensitivity due to perceptual learning. Here we study the interaction of these two phenomena and present a model accounting for both. Observers were asked to indicate whether the direction of motion of a briefly presented field of random dots was to the left or right of a cued direction. Stimuli were presented by method of constant stimuli with directions of motion chosen from a non-uniform distribution designed to induce a bias. This was achieved by manipulating the frequency with which different directions of motion were presented: for both the left and right halves of the stimulus distribution the left end of the range was shown few times and the right end of the range was shown many times. Observers trained on this task for an hour a day for five consecutive days. The data reveal both a bias in perceived direction of motion due to adaptation and a reduction in discrimination threshold due to learning. Both phenomena asymptotically approach some maximum magnitude both within and across days with some of the effects carrying over from one day to the next. These results are consistent with a model based on a process where stimuli induce slight changes in the tuning of neural populations coding for motion direction, namely in the width of the tuning functions and their preferred directions. Such alterations of these tuning functions are in line with physiological measurements and similar models have been used to explain various phenomena associated with long-term exposure to the image statistics of natural scenes (e.g. Girshick, Landy & Simoncelli, 2011, Nature Neuroscience).

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Sunday AM

Sunday Morning Posters

Perception and action: Reaching and grasping

Sunday, May 18, 8:30 am - 12:30 pm
Poster Session, Jacaranda Hall

33.301 **Informed perception: Catching ability changes perceived size of ball** Nathan Tenhundfeld[1](nlt4au@rams.colostate.edu), Jessica Witt[1]; [1]Cognitive Psychology, College of Natural Sciences, Colorado State University

Action-specific perception research aims to understand the role that performance plays in what we see. Softball players that are hitting better than others see the ball as larger (Witt & Proffitt, 2005). The current study aims to further understand the role that difficulty and performance have on perception. Participants were shown a squash ball and a can (either a squash ball can, or a larger racquetball can) that they would use to catch the ball. They completed 10 practice trials for which they were asked to classify various-sized circles on a computer monitor, ranging from 3.18cm to 4.45cm in size, as being bigger or smaller than the ball. Participants were then rolled the ball 3 times randomly, to the left, right, and center, for a total of 9 trials. After this catching task, they were asked to make binary classifications again. The entire process was repeated with the other cup. Data were analyzed for participants who more successfully caught the ball with the larger than the smaller cup (n=30). The Point of Subjective Equality (PSE) was calculated for each participant. A paired samples t-test indicated a significant difference between PSEs for the small and large can conditions $t(29)=2.51$, $p=.02$. When catching with the small can, the ball appeared smaller (M=3.80 cm, SD=.23) than with the big can (M=3.88 cm, SD=.19). Surprisingly, while there was a significant effect for women (n=19) $t(18)=2.94$, $p=.01$, there was not a significant effect for men (n=11) $t(10)=.19$, $p>.05$. These results provide further support for the idea that one's ability to act in their environment affects what they see, and illustrate an opportunity for further research into gender differences in perception.

33.302 **The "Verge-Weight" Illusion** Michael Barnett-Cowan[1,2](mbc@uwaterloo.ca), Gavin Buckingham[1,3], Jody Culham[1]; [1]Psychology, The Brain and Mind Institute, The University of Western Ontario, [2]Kinesiology, The University of Waterloo, [3]School of Life Sciences, Heriot-Watt University

Our expectations of how heavy an object will be allow us to use the appropriate level of force to lift an object without having to rely on sensory feedback. After lifting an object from the verge of a table edge, we noted an appreciable change in the perceived weight of the object from when it was lifted from the table's center. To assess this in the lab, in a between-subjects design we had right-handed participants lift objects with their right hand from either the center, left edge, or right edge of a table, or from a pedestal with the same surface area as the base of the objects. On each trial, participants lifted one of three identically shaped cubes of different mass and reported the perceived weight of the object by magnitude estimation. The results show that observers persistently perceive objects placed at the left or right verge of a table edge as weighing more than those placed at the center of the table or those lifted from a pedestal. Comparing grip force rate of change between the index and thumb revealed force being exerted faster for the digit facing toward the table edge (i.e., index finger for right table edge) but only on the first lifting trial. This unexpected 'verge–weight' illusion (VWI), which was found for all objects tested, persisted long after initial errors in grip force rate had been corrected. Our results suggest that the affordance objects have for falling when placed at the verge of a support surface is used by the human sensorimotor system to apply grip force in an initially protective manner. The persistence of the VMI over successive lifts suggests that the perceived weight of objects remains biased from visual heuristics of object stability.

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33.303 **Online control of grasping for shapes defined by second-order contours** Jeffrey Saunders[1](jsaun@hku.hk), Zhongting Chen[1]; [1]University of Hong Kong

When picking up smooth objects with complex shape, we tend to grasp at particular contact points that minimize slip and torsion. We have recently found that observers can quickly adjust movement and adopt ideal grasp points when an object is unexpectedly changed during an ongoing movement. This study tested whether shape processing for online control of grasping can utilize second-order contour information. The dorsal processing stream is thought to be less sensitive to second-order stimuli, so it might be difficult to make fast, online corrections to grasp points when shapes are specified by second-order contours. We recorded finger positions as observers reached to grasp virtual planar objects with smooth, random shapes. On perturbed trials, the initial object was replaced by a new object with different shape after the movement had begun, and observers adjusted their movement to grasp the new object. Three stimulus conditions were compared. In the baseline condition, stimuli were solid colored 2D shapes on a darker background. In the second-order condition, a visible contour was created by inverting a region of a low-pass noise pattern corresponding to the interior of a shape. A coherent shape can be perceived from the integrated boundary edges, which change luminance polarity along the contour. In a third condition, the base images were high-pass filtered, which removes low frequencies but preserves polarity of edges along the contour. In all conditions, we observed smooth corrective responses to perturbations, resulting in final grasp points that were near optimal and equivalent to the grasp points of unperturbed trials with the same object. We found no differences between the three stimulus conditions; performance was as accurate for the second-order contours as for shapes specified by luminance difference. The visual-motor system appears to be capable of robust shape processing for online control of grasping.

Acknowledgement: Supported by Hong Kong Research Grants Council, GRF 753211

33.304 **Fast Processing of Shape Information for Online Control of Grasping** Zhongting Chen[1](u3001782@hku.hk), Jeffrey Saunders[1]; [1]University of Hong Kong

When picking up objects with a precision grip, we tend to grasp at contact points that minimize slippage and torsion. For smooth objects with complex shape, the set of ideal grasp points is limited and depends on the particular shape. In normal conditions, grasp points could potentially be determined during a planning stage prior to movement. This study tested whether the visual motor system can identify appropriate grasp points during an ongoing movement. We used a perturbation method to isolate online control of grasping. Observers reached to grasp virtual planar objects with varied shapes. On a subset of trials, the object was changed after the onset of movement by either rotating the object by 45° (Experiment 1) or by replacing with an entirely different object (Experiment 2). Optimality of the final grasp points was evaluated by two measurements: torque control and force closure control (Blake, 1992). With or without perturbations, grasp axes passed close to the center of mass (1mm deviation on average), and had small angular deviations from the surface normals (average force closure angle of 25°). Corrective adjustments in response to perturbations were detectable within 100ms of perturbation onset. There was no slowing of the hand or increase in movement duration on perturbed trials, and final grasp points showed no reduction in optimality relative to unperturbed trials with the same object. These results demonstrate that the visual-motor system is capable of rapid, online processing of shape information for guiding the hand to optimal contact points during grasping.

Acknowledgement: Supported by Hong Kong Research Grants Council, GRF 753211

33.305 **Reach-to-grasp actions affect the perceptual scaling of disparity-defined depth.** Carlo Campagnoli[1](carlo_campagnoli@brown.edu), Fulvio Domini[1,2]; [1]Department of Cognitive, Linguistic & Psychological Sciences, Brown University, [2]Center for Neuroscience and Cognitive Systems@UniTn, Italian Institute of Technology

In previous studies it has been found that the perceived structure of 3D objects can be affected by non visual factors, such as the observer's reach capability (Volcic et al., 2013). Here we investigate whether an actual motor execution affects perception of 3D structure from binocular disparities. Participants saw a disparity defined three-rod configuration in which a central rod was in front of two flanking rods located at the same depth plane (orthogonal to the sagittal plane), so to form an isosceles triangle with the apex centered along the line of sight. In a 2AFC task subjects were asked to judge whether this triangle was deeper or shallower than an equilateral triangle. The depth of the triangle (i.e. the depth separation between the front rod and the flanking rods) was varied across trials with a staircase procedure, allowing us to determine the value at which each participant perceived an equilateral triangle. In two separate blocks participants either simply looked at the three-rod configuration (Visual condition) or reached to grasp it before making the perceptual judgment (Motor condition). The reach-to-grasp action did not provide any additional information about the depth or location of the three-rod configuration, since subjects could neither see their hand of feel the object. The order of the two blocks was counterbalanced across subjects. We found that (1) the three-rod configuration appeared shallower in the Motor condition than in the Visual condition and (2) subjects who performed the Motor condition first perceived the depth of the triangle in the Visual condition as shallower than subjects who performed the Visual condition first. These results indicate that a reach-to-grasp action affects perceived disparity defined depth, suggesting that uninformative proprioceptive signals influence the scaling of binocular disparities. Surprisingly this influence lasts well after proprioceptive signals are no longer available.

33.306 **Distinct patterns of size-contrast illusion effects in reaching and grasping movements** Christine Gamble[1](christine_gamble@brown.edu), Joo-Hyun Song[1,2]; [1]Department of Cognitive, Linguistic and Psychological Sciences, Brown University, Providence RI, [2]Brown Institute for Brain Sciences, Brown University, Providence RI

Past studies using size-contrast illusions to dissociate the dorsal and ventral streams and examine their roles in visually-guided action have focused on different types of movements, and yielded contradictory findings on the influence of perception on action. Here, we examine how the Ponzo illusion influences visually-guided reaching and grasping movements under the same conditions. In our Ponzo illusion paradigm, two identical circles were presented on the left and right sides of a screen with converging lines on one side causing the "inner" circle to appear larger than the "outer" circle. To assess individual susceptibility to this illusion, participants used a keyboard to adjust the sizes of outer target circles to perceptually match inner reference circles, consistently making outer targets larger than inner references in accord with the illusion. Using the adjusted circle size for each participant, we created a condition in which the two circles were perceptually the same size, but physically different (perceptual size match) in addition to the aforementioned standard illusion condition (physical size match.) We also included two control conditions reflecting the different physical sizes in the experimental conditions, but with parallel lines that fail to produce an illusion. We recorded movement time (MT) and maximum grasp aperture, respectively, during reaching and grasping movements, and calculated a difference in MT and aperture between the two circles in each of the four conditions. We then correlated this difference in the physical size match and perceptual size match conditions with the difference between the physically different controls. We found that perceptual rather than physical size determines MT in reaching, whereas physical size primarily influences grasp aperture. However, grasp aperture also appears to be impacted by perceived size to a lesser extent. Thus, the patterns of size contrast illusions' influence on action are inherently different for reaching and grasping movements.

33.307 **Hand position influences perceptual grouping** Greg Huffman[1](greg.huffman@mail.utoronto.ca), Davood Gozli[2], Jay Pratt[3]; [1]Department of Psychology, University of Toronto, [2]Department of Psychology, University of Toronto, [3]Department of Psychology, University of Toronto

Over the past five years, several studies have shown that visual and attentional processing is altered near the observers' hands. One explanation for these effects suggests that placing the hands near visual stimuli increases the contribution of the magnocellular (M) pathway and decreases the contribution of the parvocellular (P) pathway (Gozli, West, & Pratt, 2012). Given the role of the M-pathway in integrating information across space, the current study examines if hand position is also capable of influencing perceptual grouping. To accomplish this, we used a modified version of the Kramer and Jacobson (1991) task in which target-flanker gestalt grouping and target-flanker distance are manipulated. For this experiment, participants judged whether a vertical target line presented at fixation was dotted or dashed while they had their hands near (on the monitor) or far (on the keyboard) from the stimuli. The critical manipulation was that the target line was flanked by two dotted or dashed lines, grouped into the same or separate objects as the target line, appearing at varying distance on the left and right of the target line. It was previously found when target and flankers belong to separate objects there is a reduced flanker congruency effect. This effect was replicated in the far-hands condition, but in the near-hands condition flankers belonging to separate objects continued to cause a congruency effect. These results are consistent with the visual pathway account: in far-hand space object-based processing (P pathway) dominates performance while in near-hand space location-based processing (M pathway) is the main driver of performance.

Acknowledgement: Natural Science and Engineering Council

33.308 **Enhanced Visual Processing When Reaching for Targets Presented Near the Hands** Karolina Beben[1](karolinabeben@trentu.ca), Liana Brown[1]; [1]Psychology, Trent University

Placing a hand near a target seems to influence how it is processed. One possible explanation for near-hand effects is that bimodal neuron recruitment contributes to a more robust representation of targets appearing near the hands in comparison to targets far from the hands. Neurophysiological studies have shown that near-hand targets recruit visual-tactile bimodal cells, and that the response of these cells varies with the distance between the target and nearby hand. The purpose of the current study is to determine if the representation of target location for reaching is influenced by the presence of the hand near the target. Participants reached for targets that appeared either near or far from (1) the participant's invisible resting left hand or (2) a visual cue (absence of left-hand). We predicted that if hand-proximity effects arise from the recruitment of visual-tactile bimodal cells then participants should reach for targets more quickly and with greater accuracy and precision when the hand is in the workspace, and that these measures should vary with the distance between the hand and target. Right-hand reaching movements were tracked using a motion tracker to measure movement timing, end-point accuracy and precision. Our results showed that when the resting hand was present there was a reduction in spatial error, error variability, and movement time when compared to the no-hand condition. Likewise, these measures varied significantly with the distance between the target and hand. Overall, these results suggest that the visual representation of the target is enhanced through the recruitment of multisensory resources when the target appears near but not far from the hand.

33.309 **Influence of Visual Feedback on Gaze-Dependent and Location-Dependent Errors in Grasp Location and Orientation** Noura Alomawi[1,2,3](omawino@yahoo.com), Joost C. Dessing [4], Xiaogang Yan [2,3], J. Douglas Crawford [1,2,3]; [1]Kinesiology and Health Science, [2]Center of Vision Research, [3]York University, Toronto, Canada, [4]Queen's University, Belfast

Previous studies have shown that visual feedback from the target and the hand is important to plan, guide, and enhance the accuracy of pointing and reaching movement (e.g. Berkinblint et al. 1995; Blohm et al. 2007). A recent study showed that providing visual feedback about the hand supresses gaze dependent errors (Dessing et al. 2012). In a previous report (AlOmawi et al. 2013) we used a reach to grasp task that involves precision grip and hand orientation during open loop condition to investigate the influence of gaze and target positions on the transport and orientation components of the hand. This paradigm utilized rectangular 'virtual' targets presented at 3 orientations, 3 locations, and with 3 gaze fixation positions. Here we altered this paradigm to investigate the influence of visual feedback (VF) from the target, hand, or both on gaze- and location- dependents errors. Seven subjects reached to grasp the target during four VF conditions; brief target presentation with no further feedback (No VF), prolonged vision of the target (Target VF), the prolonged vision of the hand (Hand VF), or both (Full VF), all semi randomized within the testing blocks. We found that reach location errors related to gaze and target location were highly correlated for all subjects (0.622 <0.96, P <.001) between the No VF and Target VF, whereas, Full VF errors correlated to Hand VF errors (0.472 <0.99, P<.001). Hand VF increased the variability of reach location errors, while Target VF reduced the variability. However, the modulation of Hand and Target VF was dependent on the direction of the reach stimulus and gaze. In contrast, there was no influence of VF in grasp orientation errors. Our results suggest that grasp location and orientation are controlled separately, and are differentially influenced by hand position and target feedback, respectively.

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33.310 **The role of egocentric and allocentric feedback in calibrating goal-oriented actions** Chiara Bozzacchi[1](chiara.bozzacchi@iit.it), Robert Volcic[1], Fulvio Domini[1,2]; [1]Center for Neuroscience and Cognitive Systems@UniTn, Istituto Italiano di Tecnologia, [2]Department of Cognitive, Linguistic & Psychological Sciences, Brown University

Object-oriented actions require the computation of egocentric (subject reference) and allocentric (object reference) spatial features. However, systematic biases in the estimation of object distance and size occur when the visual feedback of the hand and the haptic feedback of the object are absent. In the present study, we investigated whether training with feedback about object position, with or without feedback about object size, calibrates object-oriented actions. In four experiments we combined grasping and reaching tasks with egocentric and allocentric feedbacks: i) grasping task with vision of the thumb, ii) grasping task with vision of both the thumb and the index finger, iii) grasping task with vision of the thumb and tactile feedback of both the thumb and index fingers, iv) reaching task with vision and the tactile feedback of the thumb. All experiments were divided into three separate blocks: pre-training (vision of the object only), training (one of the different feedback conditions), post-training (vision of the object only). Objects were random-dot elliptic cylinders with varying relative depth (20, 40 mm) rendered in stereo and presented at different viewing distances (420, 470, 520 mm) with consistent vergence and accommodative information. We analyzed the terminal hand position and the terminal grip aperture before and after training. The accuracy of the terminal hand position improved in the first and fourth experiment after training with only egocentric feedback. In particular, this calibration was more effective in the reaching than in the grasping task. On the contrary, no effect on the transport component was found in the second and third experiment, in which both egocentric and allocentric feedbacks were provided. None of the training blocks calibrated the terminal grip aperture. These findings suggest that the simultaneous presence of egocentric and allocentric feedbacks hinders, instead of promoting, action calibration.

33.311 **The role of reference frames for reaching in a naturalistic environment** Katja Fiehler[1](katja.fiehler@psychol.uni-giessen.de), Christian Wolf[1], Mathias Klinghammer[1], Gunnar Blohm[2]; [1]Experimental Psychology, Justus-Liebig-University Giessen, Germany, [2]Centre for Neuroscience Studies, Queen's University, Kingston, Ontario, Canada

When interacting with our environment we generally make use of egocentric and allocentric object information by coding objects relative to the observer or relative to the environment, respectively. Bayesian theories suggest that the brain integrates both sources of information optimally for perception and action. However, experimental evidence for egocentric and allocentric integration is sparse and moreover has only been studied using abstract stimuli lacking ecological relevance. Here, we investigated the use of egocentric and allocentric information during reaching in natural scenes. Participants encoded a breakfast scene containing 6 objects on a table (local objects) and 3 objects in the environment (global objects). After a 2s delay, a visual test scene reappeared for 1s in which one local object was missing (=target) and the remaining one, three or five local objects or one of the global objects were shifted to the left or to the right. The test scene was followed by a grey screen which signaled the participant to reach to the target as precisely as possible. When shifting objects we predicted no change in reaching endpoints if participants used egocentric object coding and large shifts of endpoints if allocentric information (local or global) dominated. We found that reaching movements were most affected by local allocentric shifts showing an increase in endpoint errors with the number of local objects shifted. Allocentric weights ranged between 10% and 40% depending on the number of shifted local objects, but there was no consistent effect of global allocentric cues. We are currently testing whether and how reach trajectories are affected by spatial shifts of local and global objects in the scene. Our findings suggest that allocentric cues are indeed used during goal-directed reaching. Moreover, the integration of egocentric and allocentric object information seems to depend on the ecological relevance of the available allocentric cues.

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33.312 **Visually judging the fate of one's own and others' basketball shots** Rouwen Cañal-Bruland[1](r.canalbruland@vu.nl), Lars Balch[1], Loet Niesert[1]; [1]MOVE Research Institute Amsterdam, Faculty of Human Movement Sciences, VU University Amsterdam, The Netherlands

Skilled basketball players are more successful from the free-throw distance than would be predicted by their performances at adjacent distances. This is referred to as an especial motor skill. In this study, we examined whether especial motor skills map onto the ability to visually judge the fate of basketball free-throws more successfully than would be predicted by visual judgments at other shooting distances. In addition, we tested whether such an especial perceptual skill would exist when judging one's own shots but not those performed by others. Eight high-skilled basketball players were paired to eight equally skilled players, and asked to perform 150 set-shots from five systematically different distances (including the free-throw distance) while the partner observed the shots. At the moment of ball release, vision of both the performer and the observer were occluded using liquid-crystal occlusion goggles, and both independently judged whether the shot was successful or not. Auditory feedback was withheld. Results did not replicate the previously reported especial skill effect in motor performance. That is, players did not shoot significantly better at the free-throw distance than was predicted by the performances from adjacent distances. Yet, despite the lack of an especial motor skill, Signal Detection Theory (SDT) analyses revealed that performers demonstrated greater sensitivity when discriminating hits from misses at the foul line than was predicted by discrimination judgments at adjacent distances. In addition, performers also showed a response bias to judge more free-throws to be 'in' than was predicted by the bias measures at other distances. Importantly, both effects were unique to the performers, and not found in the observers. Together, independent of the actual occurrence of especial motor skills in shooting performance, skilled performers indeed possess especial perceptual skills and show a response bias towards judging balls 'in' when judging the fate of free-throws.

33.313 **Limb-target regulation processes: Further evidence for a sweet spot.** Valentin Crainic[1](valentin.crainic@mail.utoronto.ca), John de Grosbois[1], Tifanny Lung[1], Arindam Bhattacharjee[2], Luc Tremblay[1]; [1]University of Toronto, [2]McMaster University

Recently, we proposed that limb-target regulation processes are primarily based on visual feedback that is available when the limb travels between 1.0 and 1.1 m/s (Tremblay et al. 2013a). We have also observed that perceptual judgments of endpoint accuracy are better when a brief visual window (20 ms) is provided when the limb travels at 1.0 m/s, compared to faster and slower limb velocity criteria (Tremblay et al. 2013b). In this study, we implemented a target jump procedure. We reasoned that if limb-target regulation processes are more likely to take place at limb velocities neighbouring 1.0 m/s, then participants should more effectively amend their trajectory to a target jump presented at 1.0 m/s, compared to other limb velocities. Thirteen participants were asked to maintain their gaze on their finger until a go signal (target and brief tone, presented for 20 ms), which prompted them to perform a reaching movement as accurately as possible while maintaining a 325-375 ms movement time bandwidth. Participants performed 20 control trials with vision throughout the movement (full vision). In addition, they performed reaching movements with 20 ms of vision combining 3 limb velocity conditions (0.6, 1.0, 1.4 m/s: before peak velocity) with 2 target conditions (no-jump: 30 cm, jump: 27 cm). Participants performed 30 trials under each velocity condition while the target jump occurred on 10 of these 30 trials. By contrasting the no-jump and jump trials separately for each velocity condition, we observed that participants exhibited longer movement times, longer times spent in the deceleration phase, and shorter reaching amplitudes with the 1.0 m/s condition only. Therefore, we provide further evidence for the predominance of limb-target regulation processes when the limb velocity reaches 1.0 m/s (or the corresponding time or position of the trajectory) compared to other limb velocities.

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33.314 **Coupling of reaction and movement times in reaching** Cristina de la Malla[1,2](c.delamalla@gmail.com), Joan López-Moliner[1,2]; [1]Vision and Control of Action Group, Departament de Psicologia Bàsica, Universitat de Barcelona, [2]Institute for Brain, Cognition and Behavior (IR3C)

Two main components are considered in reaching movements towards a target: the reaction time (RT, the time between target onset and movement initiation) and the movement time (MT, from movement onset to movement offset). RT is often used as a signature of action planning. We are interested in how both components are coupled and whether they can be controlled independently of each other. We designed a task in which subjects saw a red target that turned green to signal the response period after 0, 0.25, 0.50, 1, 2 or 5 seconds contributing to different degrees of movement planning. After the color change, subjects had to reach the target in 800 ms. In different conditions this time could refer to the duration of the whole movement including RT (RT+MT) or only to the duration of the MT. Results show that the longer the time to plan the movement, the shorter the RT but also (and unavoidably) the longer the MT. Although this coupling could be useful for the RT+MT condition because they com-

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pensate one another, it generates systematic temporal errors when the MT has to be controlled independently. The same coupling is found in a task in which subjects are required to make a ballistic movement towards the target. In this task there were not temporal restrictions, but yet MT kept increasing with planning time, resulting in the reported RT-MT coupling. The increase of the MT involved smoother movements, therefore, this automatic coupling could reflect some basic optimization principle when performing the movements that can eventually override the goal of the task (e.g.: perform a movement within some temporal boundaries).

33.315 **Computational Models of Extra-Retinal Contributions to Predictive Saccades** Gabriel Diaz[1](gabriel.diaz@rit.edu), Mary Hayhoe[2], Tommy Keane[1]; [1]Rochester Institute of Technology, [2]University of Texas at Austin

When preparing to intercept a ball in flight, humans make predictive saccades ahead of the ball's current position, to a location along the ball's future trajectory. Such visual prediction is extremely accurate for even non-athletes, and can reach at least 400ms into the future. Furthermore, prediction is not simple extrapolation, but draws upon prior experience to account for likely target dynamics. This was demonstrated in a virtual-reality ball interception task in which subjects were asked to intercept an approaching virtual ball shortly after its bounce upon the ground. The subject's hand and eye movements were tracked with motion capture and an eye-tracker as they attempted to intercept a virtual ball seen through a head-mounted display. On the majority of trials, subjects made pre-bounce saccades to a location along the ball's eventual post-bounce trajectory, where they would fixate until the ball passed within 2˚ of the fixation location. Furthermore, the saccades demonstrated prediction of the eventual height of the ball at the time of the catch. In the current study, we use computational models to better understand the guidance of these eye-movements. Subjects performed an interception task in which fast moving balls left little time to guide the interceptive movement on the basis of the post-bounce visual information. Thus, at the time of the bounce, subject's hand height was predictive of the ball's arrival height. We modeled predictive hand placement as a combination of pre-bounce visual information and the predicted final arrival height (as indicated by the predictive saccades). Through a process of computational modeling, we can differentiate between behavior that is either biased towards a central tendency, that suggests a learned mapping between hand position and pre-bounce kinematics, or that indicates reliance on a Bayesian prior.

33.316 **Invariant and variable relations emerge with degrees of difficulty within habitual and surprise touch-pointing motions** Vilelmini Kalampratsidou[1](vilelmini.kalabratsidou@gmail.com), Elizabeth Torres[2]; [1]Computer Science Department, [2]Psychology Department

Movements are inherently variable. The patterns of variability as we perform motions repetitively can inform us of control strategies within the nervous system. Often we study the endpoint variability in reaching actions but less explored are the patterns of variability as the action unfolds. In this work we study the patterns of variability as the person habituates to the drawing of geometric figures with vertices prompted ahead, as the hand habituates to the touches of points that appear in succession. As the motions become highly predictive of the next vertex location and the subjects naturally gain speed, we throw in a surprise point at an unexpected location. Under these circumstances we study the interactions between various kinematic parameters at the level of the end effector and also within a subset of the joint angles of the arm (7 degrees of freedom). We ask if any relationships self-emerge during these interactions between habitual and surprised motions for spatio-temporal kinematics parameters. We used 5 levels of difficulty including two points (forming a line), three points (a triangle), four points (a square), six points (hexagon) and 11 points with increasing number of surprise points randomly thrown in the sequence. We tested already 5 participants (ongoing experiments) and found across all cases, independently of the number of vertices or surprise points, a linear relationship between the distance from point to point (in pixels) and the speed of the motion (pixels/ms). Yet across subjects the relationship between the time (ms) from point to point and the speed of the motion was non linear and well characterized by a power law with different exponents for different levels of difficulty. We discuss our results in the context of Fitt's Law and report on new findings concerning the joint angles' patterns of variability.

Acknowledgement: NSF

33.317 **Another look at binocular vision: Contribution to online control processes.** Damian Manzone[1](damian.manzone@mail.utoronto.ca), Arindam Bhattacharjee[2], John de Grosbois[1], Gerome Manson[1], Tristan Loria[1], Tiffany Lung[1], Luc Tremblay[1]; [1]University of Toronto, [2]McMaster University

Ample research has investigated the advantage of binocular over monocular vision. In this study, we aimed to better understand the use of monocular vs. binocular visual feedback for the control of on-going upper-limb reaching movements. If binocular cues (e.g., binocular disparity) contribute to such online control processes, then participants should exhibit wider endpoint distributions when performing with one vs. two eyes. Twelve right-eye and right-hand dominant individuals performed reaching movements (30 cm) with counterbalanced presentation of monocular dominant, monocular non-dominant and binocular vision conditions. We analysed movement endpoint accuracy and precision. As anticipated, participants exhibited wider endpoint distributions in the primary movement axis, with both monocular conditions compared to the binocular condition. In addition, we performed contrasts between limb position at 25%, 50% and 75% of movement time and limb position at movement end. Such correlational analyses presumably reflect the extent to which movements are corrected between movement onset and offset (e.g., Heath, 2005). Further, analysis of the Fisher-z transformed R values showed that participants exhibited more stereotyped (i.e., less controlled) trajectories in the monocular dominant condition compared to the binocular vision condition. The contrast between monocular non-dominant and binocular vision failed to reach significance. These results provide evidence that individuals employ binocular cues (e.g., binocular disparity) to implement online trajectory amendments while vision with the dominant eye vs. the non-dominant eye contribute differently to the control of on-going movements.

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33.318 **Does binocular vision drive the lower visual field advantage for grasping?** Stephanie Rossit[1](S.Rossit@uea.ac.uk); [1]School of Psychology, University of East Anglia, UK

Humans achieve better performance when reaching and grasping stimuli positioned in the lower than in the upper visual field. Moreover, the brain regions involved in visuomotor control also show a lower visual field preference for hand actions (e.g., Rossit et al., 2013). The current study investigated whether the lower visual field advantage for grasping is related to the availability of binocular cues. Right-handed participants were asked to fixate on one of two light-emitting diodes such that objects could appear in either the upper or lower right visual fields. While keeping fixation, they were required to reach out and grasp objects under conditions of either monocular or binocular vision. Grasping movements were performed towards self-illuminated objects in open-loop and simultaneously with a fixation task. In line with previous studies, the analysis of kinematic parameters revealed that under monocular viewing, grip apertures were larger than under binocular viewing. Moreover under both binocular and monocular viewing, grip apertures were less variable when objects were viewed in the lower as opposed to the upper visual field. In addition, under binocular viewing there was a stronger relationship between object size and grip aperture when objects were presented in the lower visual field as compared to in the upper visual field, whereas no visual field effect was observed in the monocular condition. These results indicate that binocular cues may play an important role in the lower visual field advantage for grasping. In particular, the availability of binocular cues may allow better programming of grip scaling specifically towards objects in the lower visual field, reflecting the fact than in our everyday lives this is the region of space where we mostly interact with objects.

33.319 **Visually guided grasping in depth is systematically inaccurate** Claire Walker[1](claire_b_walker@brown.edu), Carlo Campagnoli[1], Fulvio Domini[1,2]; [1]Department of Cognitive, Linguistic & Psychological Sciences, Brown University, [2]Center for Neuroscience and Cognitive Systems@UniTn, Italian Institute of Technology

Current theories postulate that the visual system is divided into two parallel pathways: a dorsal stream that guides motor actions and a ventral stream for conscious perception and recognition of objects. It has been hypothesized that the dorsal stream has access to accurate 3D information. However, recent empirical findings cast serious doubts on this hypothesis, since we found that reach-to-grasp actions are highly inaccurate when visual feedback of the hand and haptic feedback of the objects are absent (Campagnoli et al., 2012; Foster et al., 2010). Here we investigated to what extent the visual feedback of the limb may improve the accu-

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racy of a reach-to-grasp action. Participants were asked to grasp along the depth axis a virtual, disparity-defined vertical cylinder. In different trials, the simulated cylinder had different diameters (30 mm and 50 mm) and appeared at two different distances (280mm and 400mm). The cylinder was visible throughout every trial, whereas the visual feedback of the tips of the grasping fingers (e.g. index and thumb) was present from the start of the grasping action until the fingers reached a specified distance from the cylinder. In six consecutive blocks, this distance was 70mm, 30mm, 20mm, 15mm, 10mm, and 5 mm. In two control blocks, the visual feedback was either absent altogether (first block) or always present (last block). In all conditions, the Final Grip Aperture (FGA) was highly inaccurate, showing that the visual feedback of the fingers is not sufficient for an accurate reach-to-grasp action. Interestingly, we observed a dramatic improvement in FGA accuracy from the 70mm block to the 30mm block. However, no further improvement was observed in subsequent blocks (30 – 5 mm). These results are in contrast with the hypothesis that the dorsal stream performs a veridical metric analysis of objects for motor action.

33.320 **Dissociating Action and Perception Using a 3D Variant of the Sanders Illusion While Controlling for Visual and Haptic Feedback** Kate E. Merritt[1,2](merrittk91@gmail.com), Robert L. Whitwell[1,3,4], Gavin Buckingham[5], Philippe Chouinard[1], Melvyn A. Goodale[1,3]; [1]The Brain and Mind Institute, The University of Western Ontario, London, ON, Canada, [2]The Department of Physiology and Pharmacology, The Univeristry of Western Ontario, London, ON, Canada, [3]The Department of Psychology, The University of Western Ontario, London, ON, Canada, [4]The Graduate Program in Neuroscience, The University of Western Ontario, London, ON, Canada, [5]Department of Psychology, School of Life Sciences, Heriot-Watt University, Edinburgh, UK

According to the two visual systems hypothesis (TVSH), 'vision-for-action' and 'vision-for-perception' are mediated by two distinct anatomical cortical pathways. Supporting evidence for the TVSH has come from neuropsychological, neurophysiological, and neuroimaging studies of humans and non-human primates. One particularly contentious line of evidence, however, has come from studies that have shown stronger effects of pictorial illusions on perceptual estimation tasks than on grasping tasks. Critical re-appraisals of these studies have rendered the perception-action dissociation interpretation problematic, noting confounding task-differences in attention, stimulus-response functions, obstacle avoidance, and visual and haptic feedback. Here, we asked participants to either reach out and pick up (length-wise) target bars embedded in the Sanders parallelogram illusion or perceptually estimate their lengths. We removed online and offline sources of visual feedback by suppressing the participants' vision throughout their grasps. We controlled for haptic feedback by administering the grasping and perceptual estimation tasks in an alternating task schedule. Thus, participants had the same opportunity to touch the targets in the perceptual estimation task as they did in the grasping task. Furthermore, we administered each task in a more traditional manner by separating them into two blocks of trials. The results of our experiments were clear. In line with the TVSH, the illusory effect of the Sanders display was significantly weaker on grasps than on perceptual estimates when the tasks was blocked separately and when the perceptual estimation and grasping tasks were alternated from trial to trial. In addition to this key finding, there was no evidence to suggest systematic between-task differences in the response functions to target length. Not surprisingly, therefore, an analysis of the 'corrected' illusory effects supported our key findings. We conclude that the Sanders illusion reveals robust positive evidence for separate visual-perceptual and visuomotor systems in neurologically-intact populations.

33.321 **Judging Speed of Baseball Pitches in a Batting Cage** Michael K. McBeath[1,2](m.m@asu.edu), Richard N. Hinrichs[2], Jeremy R. Babendure[3]; [1]Psychology, Arizona State University, [2]Kinesiology, Arizona State University, [3]Arizona SciTech, Arizona State University

Introduction: Hitting a baseball is often described as the hardest thing to do in sports. Here we examine ability of untrained observers to estimate speed of pitched baseballs from a batter's perspective in a real-world setting with near Major League Baseball hitting conditions. Participants volunteered at the Science of Baseball Festival, a promotional event sponsored by ASU, Arizona SciTech, Major League Baseball, and the city of Scottsdale. Method: 162 observers were tested in ability to judge baseball pitch speed from the perspective of a batter in a batting cage. Pitch speed randomly varied between 85 and 102 mph using a pitching-machine located at the Major League pitching-distance of 60 feet. Actual speed was measured with a speed-gun. Participants each stood behind a protective fence within the batting cage and observed and estimated speed of four pitches, with feedback after each pitch. Results: Participants were initially quite poor at discriminating between pitch speeds, producing a correlation of only r=0.027 between actual and estimated speed on their first trial. Yet, they improved asymptotically the following three pitches, respectively increasing the performance correlation to r=0.26, r=0.30, and r=0.41. Other demographic predictor variables of age, sex, and baseball experience did not relate to judgment accuracy in a systematic manner. Overall estimates initially averaged more than 3 mph too low, but converged to an accuracy within half mph by the third pitch. Discussion: While untrained observers are initially quite poor at discriminating real-life Major League pitch speeds, given feedback after several pitches, observers rapidly learn to be quite accurate. Our findings support that under real-world full-cue viewing conditions, even inexperienced observers can be remarkably adept at learning to judge very rapid motion. This supports that difficulty in hitting may be largely due to inability to coordinate perception-action rather than lack of perceptual resolution and accuracy.

Acknowledgement: Arizona SciTech Festival

33.322 **Biases in number representation as a by-product of optimising visuomotor responses: evidence from a number line reaching task** David Aguilar-Lleyda[1,2](aguilarlleyda@gmail.com), Elisabet Tubau[1,2], Joan López-Moliner[1,2]; [1]Institute for Brain, Cognition and Behaviour (IR3C), Universitat de Barcelona, Catalonia, [2]Departament de Psicologia Bàsica, Universitat de Barcelona, Catalonia

Numeric value seems to be analogically represented in a mental number line, with value increasing from left to right. In traditional number line tasks, participants estimate the position a number would have on a line representing a numerical range. While some views claim a logarithmic or a linear representation, the fact that part/whole decisions are made led others to defend that these tasks are better interpreted as proportion estimation. Indeed, perceptual proportion estimation models predict a pattern of smaller number overestimation and bigger number underestimation. Plus, these models take into account reference points commonly adopted by participants – such as the line edges and center. Reaching to a number line has been used to reveal underlying cognitive processes and the nature of numeric representation scales. Here we used this task to test numeric representation on a number line. After a number appeared, participants moved a stylo over a tablet from a starting point towards the point of the line matching the number. We tested different numeric scales and target-number dispositions. Movement trajectories were straight without differences among scales, but there was a consistent pattern of under-overestimation. This bias can be interpreted as both a prior spatial-numeric representation (increasing left-to-right value) and spatial reference points affecting the endpoint estimation in the visuomotor mapping. When target disposition matched prior representation, the line edges acted as anchors attracting the endpoint. In those with a numeric discontinuity in the center, these perceptual anchors were overridden resulting in attraction towards the center. Finally, with a reversed disposition the prior substantially diminished the perceptual effect of the edges. Thus, the direction and strength of the reported underestimation-overestimation patterns (or vice versa) can be explained by different elements contributing to the selection of the final position in a way that is consistent with an optimality framework.

33.323 **"I Can Only Imagine": Effect of Task-Specific Execution on Accuracy of Imagined Aiming Movements** Emma Yoxon[1,2](emma.yoxon@mail.utoronto.ca), Luc Tremblay[1,2], Timothy Welsh[1,2]; [1]Faculty of Kinesiology & Physical Education, University of Toronto, [2]Centre For Motor Control

According to ideomotor theory, the codes that represent action and the perceptual consequences of those actions are tightly bound in a common code. It is thought that these common codes are not only used for efficient action selection and execution, but also during the imagination and perception of action. For action imagination, bound action and perceptual codes are thought to be internally activated at a sub-threshold level. In support of this hypothesis, recent research has shown that the accuracy of action imagination increased following experience executing the task. Specifically, Wong et al. (2013) observed that movement times (MTs) in imagined reciprocal aiming movements were closer to actual execution MTs after the participants gained experience completing the aiming movements. This increased accuracy was suggested to occur because the binding and refining of the common codes occurs through training and/or experience with an action and its perceptual consequences. The current study was conducted to examine the task-specific nature of the effects of experience on imagination (i.e., if improvements in accuracy of action imagination occur only with experience of the reciprocal aiming task or with any aiming task). To this end, participants were divided into two groups. One group executed a reciprocal pointing task while the second group executed a discrete aiming task with

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comparable accuracy requirements. Influence of task specificity on imagination performance was assessed by evaluating the changes in imagination MTs pre- and post-execution. Consistent with earlier findings, there was an overall change in imagined MTs following task execution. Of greater theoretical relevance, there were no reliable between-group differences in the pre/post-execution changes in MT. Therefore, it appears that the imagination of aiming movements is affected by experience with speed-accuracy demands regardless of the specific context of that experience.

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Multisensory processing: Visuo-auditory interactions

Sunday, May 18, 8:30 am - 12:30 pm
Poster Session, Jacaranda Hall

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33.324 **Auditory-induced bouncing is a visual (rather than a cognitive) phenomenon: Evidence from illusory crescents** Hauke S. Meyerhoff[1](h.meyerhoff@iwm-kmrc.de), Brian Scholl[2]; [1]Knowledge Media Research Center, Tuebingen, Germany, [2]Department of Psychology, Yale University

When two discs move toward each other, superimpose, and continue moving afterwards, observers typically perceive them as streaming past each other. If a brief tone occurs at the moment of overlap, however, then the discs are perceived as bouncing off each other. Recent research has attributed this effect to decisional (rather than perceptual) processes by showing that auditory tones alter response biases but not the underlying sensitivity for detecting objective bounces. Here we explore the nature of this phenomenon using 'illusory causal crescents': if observers view disc A move until fully overlapped with disc B, after which A stops and B moves, they may perceive either streaming or launching — but when perceiving launching, they also see B move before being fully overlapped with A (i.e. leaving an uncovered crescent). In several experiments, we measure illusory crescents in bouncing/streaming displays with auditory tones. Participants adjusted two probe discs until they matched the perceived overlap of an ongoing streaming/bouncing event. We first show that an illusory crescent emerges when the onset of a brief tone is synchronized with the moment of overlap between the two discs. We then show that the timing of this tone matters: illusory crescents still arise for tones occurring slightly earlier than the moment of maximal visual overlap, but when the tone follows the moment of maximal overlap, the crescents disappear. Moreover, the perceived "coincidence" of the tone timing is critical: illusory crescents also disappear when a perfectly-synchronized tone is heard as part of a larger repeating perceptual group of sounds. The presence of illusory crescents at all in such displays explains why observers have difficulty distinguishing objective streaming vs. bouncing. And collectively, these experiments suggest that sound-induced bouncing is a perceptual (rather than a cognitive) phenomenon, resulting from changes in visual (rather than decisional) processing.

33.325 **Correlation between Vividness of Visual Imagery and Echolocation Ability in Sighted, Echo-Naïve People** Lore Thaler[1](lore.thaler@durham.ac.uk), Rosanna Wilson[1], Bethany Gee[1]; [1]Department of Psychology, Durham University, UK

The ability of humans to echolocate has been recognised since the 1940s. Little is known about what determines individual differences in echolocation ability, however. Although hearing ability has been suggested as an important factor in blind people and sighted trained echolocators, there is evidence to suggest that this may not be the case for sighted novices. Therefore non-auditory aspects of human cognition might be relevant. Previous brain imaging studies have shown activation of the early 'visual', i.e. calcarine, cortex during echolocation in blind echolocation experts, and also during visual imagery in blind and sighted people. Therefore, here we investigated the relationship between echolocation ability and vividness of visual imagery (VVI). 24 sighted echolocation novices completed Marks' (1973) VVI questionnaire and they also performed an echolocation size discrimination task. Furthermore, they participated in a battery of auditory tests that determined their ability to detect fluctuations in sound frequency and intensity, as well as hearing differences between the right and left ear. A correlational analysis revealed a significant relationship between participants' VVI and echolocation ability, i.e. participants with stronger vividness of visual imagery also had higher echolocation ability, even when differences in auditory abilities were taken into account. In terms of underlying mechanisms, we suggest that either the use of visual imagery is a strategy for echolocation, or that visual imagery and echolocation both depend on the ability to recruit calcarine cortex for cognitive tasks that do not rely on retinal input.

33.326 **Differential effect of visual and auditory spatial cues on visual numerosity judgment** Yasuhiro Takeshima[1](yasuhiro.takeshima@gmail.com), Jiro Gyoba[1]; [1]Tohoku University

Numerosity judgment of visual objects includes various perceptual and cognitive processes. Previous studies have indicated that there are two processes in numerosity judgments—a subitizing process for up to three or four items and a counting process for over three or four items. These numerosity judgment processes are reported to reflect different types of attentional functions. However, the differential attentional effect between sensory modalities has not yet been well examined. The present study compared the attentional effect of auditory cues with that of visual cues on visual numerosity judgment. In Experiment 1, we directed attention by using the correspondence between visual stimulus elevation (top or bottom) and auditory pitch (high or low). In Experiment 2, we examined the effect of visual cues (upward or downward arrow) on visual numerosity judgment. The results indicated that auditory cues facilitated both the subitizing and counting processes. However, visual cues facilitated only the counting process, which is known to be related to spatial attention. Therefore, the present results replicated the facilitation effect on counting process by spatial attention. In contrast, the capacity of subitizing is reported to be related to working memory. Moreover, several previous studies found that spatial auditory cues improve the encoding process in visual working memory. These findings suggest that auditory cues could improve the capacity of the subitizing process and this possibility was confirmed by the present study. However, visual spatial attention did not affect the subitizing process. Therefore, visual and auditory spatial cues would have different facilitative functions in numerosity judgment.

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33.327 **Audiovisual processing differences in autism spectrum disorder revealed by a model-based analysis of simultaneity and temporal order judgments** Paula Regener[1], Scott Love[2], Karin Petrini[3], Frank Pollick[1]; [1]School of Psychology, University of Glasgow, [2]Institut de Neurosciences de la Timone, Marseille, [3]3Institute of Ophthalmology, University College London

The ability to integrate auditory and visual information is crucial to everyday life and there are mixed results regarding how Autism Spectrum Disorder (ASD) influences audiovisual integration. The audiovisual Temporal Integration Window (TIW) indicates how precisely sight and sound need to be temporally aligned to perceive a unitary audiovisual event. We used a model-based approach (Garcia-Perez & Alcala-Quintana, 2012) to compare the TIW of 26 adult males with ASD to age and IQ-matched typically developed (TD) males. The stimuli included the following audiovisual pairings with varying degrees of asynchrony: 1) a beep with a flashing circle (BF), 2) a point-light drummer with a drumbeat (PLD), 3) a face moving to say a single word and the voice saying the word (FV). In separate blocks participants were asked to make either simultaneity judgments (SJ) or temporal order judgments (TOJ) when presented with these stimuli. The model-based approach provides estimates of the TIW width as well as model parameters related to sensory and decisional factors of audiovisual processing. Analysis of the TIW width showed main effects of stimulus and group on SJ (wider TIW in the ASD group), whereas for TOJ no main effects were found. The combined model using both SJ and TOJ reported a main effect of stimulus and a marginal effect of group. Analysis of the model parameters showed group differences in both sensory and decisional factors. A decisional factor difference was found only for SJ, suggesting less temporal resolution in the ASD group. A sensory factor difference was found in the auditory but not the visual domain. This suggests that SJ is more sensitive to reveal TIW differences in ASD and that these differences appear to arise from processing differences in the auditory domain of audiovisual processing.

33.328 **Reduced audiovisual recalibration in the elderly** Yu Man Chan[1](y.chan22@student.unimelb.edu.au), Michael J Pianta[1], Allison M McKendrick[1]; [1]Department of Optometry and Vision Sciences, University of Melbourne

Exposure to a stream of temporally offset visual and auditory signals changes an observers' perception of synchrony. Previous literature suggests that adapting to audiovisual temporal offsets is needed to correctly combine audiovisual stimuli into a single percept for a range of source distances. Older people have wider synchrony windows, i.e. are more likely to perceive synchrony for visual and sound signals with larger tempo-

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ral offsets. The impact of ageing on audiovisual recalibration is unclear. Audiovisual synchrony perception for sound-lead and sound-lag stimuli was measured for fifteen younger (22-32years old) and fifteen older (64-74years old) adults using a method-of-constant-stimuli, after adapting to a stream of visual (Gabor, 10ms, 3c/deg, 85% contrast) and auditory (20dB, 10ms tone pip increment on a 75dB, 1100ms tone mask, both at 500Hz) pairs. The adaptation pairs were either synchronous or asynchronous (sound-lag of 230ms). Individual data were fitted with two Gaussian functions where window width was defined as the difference between the means of the functions fitted to the sound-lead and sound-lag conditions. The adaptation effect for each observer was computed as the shift in the mean of the fitted psychometric functions after adaptation to asynchrony. Post adaptation to synchrony, the younger and older observers had average window widths (±standard deviation) of 326(±80) and 448(±105)ms, respectively. After adapting to asynchrony, there was no adaptation effect for sound-lead pairs. The younger and older observers however perceived more sound-lag pairs as synchronous (shift in psychometric function of 94(±55) and 20(±41)ms respectively: RM-ANOVA: interaction between age and adapted condition for perceived sound-lag asynchrony ($F(1,28)=16.78$, $p<0.001$). The magnitude of the adaptation effect in the older observers was not correlated with their thresholds for asynchrony for sound-lag stimuli (Spearman's rank order correlation: $rs(13)=-0.064$, $p=0.82$). These findings show that the audiovisual synchrony window is less adaptable with age.

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33.329 **What you hear is what you see: Non-spatial visual information can hinder auditory detectability early in development** Hiu Mei Chow[1](dorischm@gmail.com), Vivian Ciaramitaro[1]; [1]Psychology Department, University of Massachusetts Boston

We combine audio-visual information readily in daily life. For example, in a noisy environment, what you hear is heavily weighted by what you see from reading the speaker's lips. While previous studies in adults have reported that visual information can influence the detectability of auditory information (for example, Bolognini et al., 2005; Lovelace et al., 2003; Oodgard et al., 2004), much less is known regarding the developmental trajectory of audio-visual interactions for basic, non-social and non-linguistic stimuli in infants. Here we examine whether visual information conveying no spatial information can influence infants' detectability of near threshold auditory stimuli. We adapted forced-choice preferential looking (FPL) to a gaze-contingent eye-tracking paradigm to quantify auditory detection thresholds in infants (3-8 months-olds). The auditory stimulus was a white noise sinusoidally-modulated in amplitude at 1 Hz, varying in maximum amplitude from trial to trial, presented to the left or right of central fixation. The visual stimulus modulated in brightness at 1 Hz and subtended the entire extent of the screen, thus conveying no lateralized spatial information. We quantified auditory detection thresholds, the auditory amplitude yielding 75% correct detection of the side of sound presentation, under 2 different visual conditions: (1) IP: auditory and visual information modulated in-phase and (2) OP: the visual and auditory information modulated out-of-phase. If synchronized visual information enhances auditory detection, we expect lower contrast thresholds for the IP condition relative to the OP condition. Our data in 3-8 month-olds suggests a worsening of performance, increased auditory thresholds and slower detection times, for the IP relative to OP conditions. These results complement our previous findings (Ciaramitaro & Dobkins, in preparation) in which a task irrelevant auditory stimulus conveying no spatial information impaired visual thresholds for an IP relative to OP condition, in 3- and 6-month-old infants.

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33.330 **Lets play it by ear: Auditory gating during goal-directed action?** Rachel Goodman[1](r.goodman@mail.utoronto.ca), Gerome Manson[1], Damian Manzone[1], Tristan Loria[1], John de Grosbois[1], Valentin Crainic[1], Luc Tremblay[1]; [1]University of Toronto

At rest, the perception of brief flashes is biased by co-occurring brief beeps (i.e., audio-visual illusion: Shams et al. 2000; Andersen et al. 2004). However, during fast and accurate goal-directed movements, susceptibility to audio-induced visual illusions is lessened, specifically during the high velocity portions of the trajectory (Tremblay & Nguyen, 2010). One explanation for such findings is the sensory gating hypothesis (e.g., Chapman & Beauchamp, 2006), which is thought to primarily occur just before and early during a movement. Employing vision-induced auditory illusions, this study tested if the modulation of the audio-visual illusion could be explained by the gating of auditory information. Thirteen participants performed rapid and accurate upper-limb movements towards a visual target. At rest and during reaching movements, 0, 1 or 2 flashes were presented simultaneously with 1 or 2 beeps. During the movement trials, these audio-visual stimuli were presented at 0, 200, and 400 ms relative to movement onset. Participants were asked to report the number of beeps heard after each trial. An ANOVA contrasted the perceived number of beeps using a 4 presentation time (rest, 0, 200, 400 ms) by 3 flash (0, 1, 2) by 2 beep (1, 2) design. On average, participants perceived fewer beeps when 1 beep was presented in the 0 ms condition, compared to the other presentation times. Further, the average number of perceived beeps was influenced by the number of flashes presented in both the 0 ms and 200 ms conditions. These results suggest that auditory information processing is suppressed as one initiates an action, while the influence of action on visual information processing takes place over a longer period of time. We conclude that auditory gating alone is not sufficient to explain modulations in the perception of the audio-visual illusion during goal-directed action.

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33.331 **Multisensory classification images reveal the role of cross-correlation in audiovisual temporal processing.** Cesare Valerio Parise[1](cesare.parise@uni-bielefeld.de), Marc Ernst[1]; [1]University of Bielefeld

The temporal relationship between signals from different modalities is a key factor for multisensory integration. In a series of recent studies we demonstrated that the similarity in temporal fine-structure between visual and auditory stimuli plays a leading role in solving the multisensory correspondence problem. Here we investigate the role of cross-correlation in multisensory integration by combining standard psychophysical techniques with reverse correlation analyses. We presented a series of auditory and visual signals that were either correlated in time or not, and we experimentally manipulated the delay between the two signals. The signals had a complex stochastic temporal structure and consisted of trains of impulses (clicks or flashes) presented over a 1.5s interval. In two separate experiments, participants reported the relative order of presentation (temporal order judgment) or whether the stimuli appeared to share a common cause or not (causality judgment). Standard psychophysical analyses revealed higher sensitivity to temporal delays for correlated signals in both causality and temporal order judgment. Notably, sensitivity to temporal delays was virtually identical in the two tasks. Additionally, in line with previous findings, temporally correlated signals were more likely reported to have a common source. Next, we used reverse correlation techniques to calculate the classification images for both tasks using the cross-correlation between visual and auditory signals. Results demonstrate that cross-correlation is indeed the factor underlying participants judgments: The sign of the lag of the cross-correlation peak correlates with temporal order judgments, whereas the amount of cross-correlation at short lags correlates with causality judgments. Overall, the present results demonstrate the primary role of cross-correlation cues in multisensory temporal processing. These findings will be discussed in the light of recent models of sensory cue integration.

33.332 **Auditory and tactile signals combine to influence vision during binocular rivalry** David Alais[1](david.alais@sydney.edu.au), Claudia Lunghi[2], Concetta Morrone[2]; [1]School of Psychology, University of Sydney, Australia, [2]Institute of Neuroscience, CNR – Pisa, Italy

Resolution of perceptual ambiguity is a major function of cross-modal interactions, making the study of bistable perception in multisensory contexts a powerful and revealing tool. We previously used binocular rivalry, a visual bistable phenomenon, to show that touch can specifically interact with vision to resolve spatial conflict between the eyes (Lunghi & Alais, 2013). Here we investigate whether auditory and tactile stimuli can influence binocular rivalry generated by temporal conflict. Using visual stimuli of different temporal frequencies (filtered dynamic noise, 3.75 vs 15 Hz) to produce visual perceptual alternations, we added an amplitude modulated sound or vibration congruent with one of the rivaling temporal frequencies. Auditory and tactile stimulation interacted with binocular rivalry by promoting dominance of the congruent visual stimulus. This effect depended on auditory/tactile stimulus strength and was absent when modulation depth declined to 33%. However, in a trimodal experiment, combining auditory and tactile stimuli that were too weak to bias rivalry on their own produced a very strong influence over vision, suggesting summation of auditory and tactile temporal signals. Similarly, interleaving discrete pulses of auditory and tactile stimuli at half-frequency promoted dominance of the visual stimulus congruent with the combined supramodal frequency. Finally, audio-tactile stimuli combined at maximum strength but in anti-phase had no influence over visual rivalry, a cancellation effect again suggesting summation of audio-tactile modulations. These results demonstrate: (i) auditory and tactile processing at low temporal frequencies is functionally linked and may share a common neural substrate; (ii) visual activity can be synchronized by a congruent cross-modal signal in a frequency-selective way, suggesting a supramodal temporal binding mechanism.

33.333 **Perceptual Biasing of a Continuous Auditory Quadri-stable Illusion** Constance Bainbridge[1](cbainbri@csail.mit.edu), Aude Oliva[1]; [1]Computer Science and Artificial Intelligence Laboratory, MIT

When perceiving multi-stable visual illusions such as the silhouette dancer illusion (Kayahara, 2003) or the Ames Window (Ames, 1951), it is easy to become trapped in a specific percept for a while before switching. The same phenomenon can occur in auditory illusions - in VSS 2013 (Bainbridge et al) we discovered a quadri-stable auditory illusion, the Transverse and Bounce Illusion. Based on front-back confusion, the sound can be perceived as having four trajectories of approaching and withdrawing from the listener. Listeners can perceive the same sound as traveling transversely through them from front-to-back or back-to-front, or they can perceive it as bouncing exclusively in front or in back. In our initial study, we found no perceptual bias when the illusion played non-continuously. Here, we recreate the illusion continuously in headphones to test its perceptual stability and the probability of switching from one state to the others. Sixteen listeners responded whether the sound was in front, in back, or at them (middle). The illusion was delivered for twenty-one blocks of one minute each, followed by a ten second break to release any perceptual locking. An untimed break was offered every seven blocks. We found listeners to be significantly biased towards perceiving the sounds travelling through them (the transverse condition), as opposed to bouncing off of them ($p<0.0001$). There was no significant difference between trials of different directions within these two conditions. During transverse percepts, listeners became significantly locked in a percept of switching back and forth between the front-to-back and back-to-front percepts ($p<0.0001$). Follow-up multi-modal studies explore how transient visual events can manipulate auditory reversal probabilities and the frequency at which people switch between auditory percepts.

Sunday AM

33.334 **Angry faces reduce sensitivity for auditory-visual temporal asynchrony** L Jacob Zweig[1](jacob.zweig@gmail.com), David Brang[1,2], Satoru Suzuki[1,2], Marcia Grabowecky[1,2]; [1]Department of Psychology, Northwestern University, [2]Interdepartmental Neuroscience Program, Northwestern University

Perception of multisensory events, such as a person speaking, relies on binding information from distinct sensory modalities into a unitary percept. A temporal window of integration for multisensory events allows flexibility to account for latency differences arising from both variable physical transmission rates through the environment and neural transmission rates within the brain (Shelton, 2010). Previous research has shown that the width of the temporal window is subject to influences of factors including attention, spatial disparity, and stimulus complexity (e.g., Spence & Parise, 2010). The extent to which the temporal window of integration for speech is influenced by emotion, however, remains unknown. In the present study, we demonstrate that an angry expression reduces temporal sensitivity for detecting auditory-visual asynchrony in speech perception. The auditory and visual streams of a video of a person uttering syllables were presented to participants at varying time delays using the method of constant stimuli. For each auditory stream, the accompanying visual stream was manipulated to assume a happy, neutral, or angry facial expression. Participants made unspeeded temporal order judgments indicating whether the auditory or visual stream occurred first. Facial expression did not influence the point of subjective simultaneity, suggesting that facial expression either does not influence the perception of speech onset or does so equally for the visual and auditory modalities. An angry expression significantly increased the just noticeable difference, suggesting that an angry expression reduces sensitivity for detecting temporal asynchronies between auditory and visual speech streams. Our result provides evidence suggesting that emotion processing influences the perception of audiovisual synchrony.

33.335 **Visual Texture, Music, and Emotion** Thomas Langlois[1](thomas.langlois@berkeley.edu), Joshua Peterson[1], Stephen Palmer[1]; [1]Department of Psychology, University of California, Berkeley

Previous research indicates that cross-modal music-to-color associations are systematic in non-synesthetes and are mediated by emotion (e.g., Palmer et al., 2013; Langlois, VSS-2013; Whiteford et al., VSS-2013). The present research asks whether similarly systematic associations are evident from music to line-based geometric visual textures in non-synesthetes, and whether they are mediated by emotional and/or non-emotional effects. We created 28 black-and-white line-based textures that differed on many geometric dimensions (e.g., the elements were lines/ segments/circles/ovals/ waves/jags and their positional distributions were in regular-grids/random-grids/regular- meshes/random-meshes). While listening to 34 widely different musical selections that varied from heavy-metal to Hindustani-sitar, 20 non-synesthetic participants picked the 3 most-consistent (and later the 3 least consistent) textures for each musical selection from a 7x4 array of black-and-white textures. Afterward, they rated each musical selection and each visual texture along 5 emotion dimensions (Happy/Sad, Angry/Not-Angry, Agitated/Calm, Weak/ Strong, Harmonious/Disharmonious), and 8 geometric dimensions (e.g., Simple/Complex, Sharp/Smooth, Granular/Fibrous). We then computed an index of music-texture associations (MTAs) for each musical selection and each rated dimension (e.g., Calm/Agitated) as a weighted average of the ratings of the 3 textures chosen as best minus the 3 chosen as worst for that selection. The results suggest that cross-modal music-to-texture associations are mediated in part by emotion, because the emotional ratings of the musical selections were strongly correlated with the emotional MTAs of the textures that were chosen as going best with the same selections (.92 for Angry/Not-angry, .94 for Calm/Agitated, .82 for Active/ Passive, .86 for Harmonious/Disharmonious). Unlike music-to-color associations, Happy/Sad was not relevant in music-to-texture associations ($r=.07$), primarily because the textures did not vary reliably in happiness/ sadness. Music-to-texture associations were also mediated by associated non-emotional features (e.g., .91 for Simple/Complex and .87 for Sharp/ Smooth). Cross-modal mappings from music to visual textures thus result from shared associations with both emotional and non-emotional content.

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33.336 **Electrophysiological Dynamics of Auditory-Visual Sensory Substitution** Christian Graulty[1](cgraulty@gmail.com), Orestis Papaioannou[1], Phoebe Bauer[1], Michael Pitts[1], Enriqueta Canseco-Gonzalez[1]; [1]Psychology, Reed College

Sensory substitution is a process by which information from one sensory modality is extracted and applied to another sensory modality. Previous fMRI studies have suggested that sensory substitution causes increased functional connectivity between auditory and visual cortices. The timing of such information transfer between sensory modalities, however, is currently unknown. The present study investigated the effects of auditory-visual sensory substitution in intact individuals by recording event related potentials (ERPs). ERPs to auditory 'soundscapes' and visual shapes were recorded before and after sensory substitution training in an experimental group using a simple sound-to-shape matching task. These participants were trained on auditory-visual pairs created by the Meijer sound-to-image conversion algorithm. ERPs to the same stimuli were recorded in a control group, before and after training, using the same matching task, however, control participants were trained to memorize random sound-shape pairs. First, to confirm that sensory substitution training was successful both groups of participants completed a transfer test on completely novel sound-shape pairs. Participants in the experimental group identified novel visual shapes based on the translated auditory information with above chance accuracy (72%) while control subjects performed at chance levels (50%). ERPs elicited by sounds and shapes were compared before versus after training within each group and the resulting ERP differences were then compared between groups. Two specific effects of sensory substitution were isolated. The auditory P2 component was enhanced post-training versus pre-training in both groups, but this difference was significantly larger in the experimental group compared to the control group. Similarly, ERPs to visual stimuli revealed increased visual N1 amplitudes as a function of training in both groups, but this difference was more pronounced in the experimental group. Taken together, the latency of these ERP modulations suggest that sensory substitution may be mediated by early interactions between auditory and visual cortical areas.

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33.337 **Subjective crossmodal correspondence and audiovisual integration** Maarten van der Smagt[1](M.J.vanderSmagt@uu.nl), Irene Buijing[1], Nathan Van der Stoep[1]; [1]Experimental Psychology, Helmholtz Institute, Utrecht University

Research on multisensory integration often makes use of stochastic ('race') models to distinguish a response performance enhancement in Reaction Times (RTs) due to multisensory integration from an enhancement due to the probability summation. Only when performance on a multisensory task supersedes that of the race-model it is attributed to multisensory 'integration'. An important factor affecting multisensory integration is the 'unity assumption', i.e. the degree to which an observer infers that two sensory inputs are of the same source or event. Apart from the obvious spatial and

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temporal correspondence, other, often more subjective, similarity estimates might play a role as well. Here we investigate how subjective crossmodal correspondence influences multisensory stimulation. Observers first matched the loudness of a 100ms white noise burst to the brightness of a 0.86° light disc (6.25 cd/m2) presented for 100ms on a darker (4.95 cd/m2) background, using a staircase procedure. In a subsequent speeded detection experiment, the observers indicated as fast and accurately as possible whether an audiovisual, auditory only or visual only target was located to the right or left from fixation. The subjectively matched loudness as well as +5dB and -5 dB loudness values were used as auditory stimuli. Auditory detection was generally faster than visual detection and audio-visual detection was generally fastest. However, only when the subjectively matched loudness was used as auditory stimulus did audio-visual detection supersede the predictions made by the race–model. This result demonstrates the importance of subjective correspondence in multisensory integration, and may explain earlier results that found a surprising lack of integration.

33.338 **Implicit detection of asynchronous audiovisual speech by eye movements** Tim J. Smith[1](tj.smith@bbk.ac.uk), Jonathan Batten[1], Rachael Bedford[2]; [1]Department of Psychological Sciences, Birkbeck, University of London, [2]Department of Biostatistics, Institute of Psychiatry, Kings College London

When watching TV or film poorly synchronised audio and video can "pop-out", drawing attention to the speaking actor's mouth. Previous studies of explicit lipsynch detection have shown that participants are quite poor at detecting asynchronies in complex speech of less than 100ms. Can the attentional capture of viewer gaze by subtle lipsynch error be used as a measure of implicit asynchrony detection? Participant eye movements were recorded while they watched a series of brief (40 x ~9s) close-up videos of people speaking to the camera. Participants were given the cover task of answering infrequent questions about the video. Each video was repeated under seven asynchrony conditions: -150ms (audio first), -100ms, -50ms, 0ms, +50ms (video first), +100ms. +150ms. After twenty videos had been shown once in each synch condition (Block 1) the same twenty videos were shown with a large asynchrony, -300ms (the Cue block). The remaining twenty videos were then shown once in each synch condition (Block 3). Analysis of participant eye movements during the cue block revealed a significant bias towards the mouth and away from the eyes (the default viewing position) and this bias did not differ between participants who reported seeing lipsynch error (i.e. explicit detection) at the end of the experiment and those that did not. After the cue, gaze was significantly shifted towards the mouth and this was most pronounced for synch conditions in which the video was first (+50 and +100ms). These results indicate that asynchronous audiovisual speech captures overt attention even when the degree of asynchrony is sub-threshold for explicit awareness and may be used as a measure of implicit asynchrony detection.

33.339 **Influences of response delay on unconscious imitation of visual speech** James W. Dias[1](jdias001@ucr.edu), Theresa C. Cook[1], Josh J. Dorsi[1], Dominique C. Simmons[1], Lawrence D. Rosenblum[1]; [1]University of California, Riverside

Human perceivers unconsciously imitate the subtle articulatory characteristics of perceived speech. This phonetic convergence has been found to manifest during live conversational interactions (e.g., Pardo, 2006) and when shadowing pre-recorded speech (e.g., Goldinger, 1998). Within the shadowing paradigm, participants say aloud the speech they perceive spoken by a pre-recorded talker. Perceivers converge along acoustical speech characteristics when shadowing auditory (heard) and visual (lipread) speech (e.g., Miller, Sanchez, & Rosenblum, 2010), suggesting the information to which perceivers converge may take a common form across sensory modalities. It is known that phonetic convergence to auditory speech decreases when perceivers are required to delay their shadowed responses, suggesting the information to which perceivers converge is subject to influences of stored memory representations encroaching upon an exemplar maintained within working memory (Goldinger, 1998). If the information to which perceivers converge when shadowing visual speech is processed similarly within working memory as the information to which perceivers converge when shadowing auditory speech, then delaying shadowed responses to visual speech should decrease phonetic convergence relative to immediate shadowing of visual speech. In the current investigation, 31 undergraduates (16 male) each shadowed 1 of 4 pre-recorded talkers (2 male). Shadowers shadowed a block of 80 auditory utterances and a block of 80 visual utterances. Each shadowed response was randomly delayed for 0, 1, 2, 3, or 4 seconds. Phonetic convergence to shadowed auditory speech was found to decrease as shadowing delay increased, $F(1,123) = 7.816$, $p < .01$, replicating previous findings (Goldinger, 1998). However, phonetic convergence to visual speech increased as shadowing delay increased, $F(1,123) = 4.823$, $p < .05$. The results suggest that, in contrast to auditory speech, the longer visual speech information is maintained within working memory, the more similar the subsequent speech production will be to the perceived speech utterance.

33.340 **Reading rotated clocks: the role of egocentric and environmental orientation** Nicolas Davidenko[1](ndaviden@ucsc.edu), Amanda Waterman[1], Yeram Cheong[1], Jake Smith[1]; [1]Psychology Department, UC Santa Cruz

Many classes of visual stimuli have a canonical orientation. Faces, animals, buildings, and other objects tend to appear at particular orientations, and behavioral studies show that we are sensitive to these canonical orientations. For example, when perceiving faces, we perform much better when faces are upright as opposed to rotated by 180° or even 90°. In recent work, we have shown that our visual system is sensitive not only to the internal (or egocentric) orientation of some visual stimuli, but also to their external (or environmental) orientation. We showed this in the perception of faces (Davidenko & Flusberg, 2012) and in the encoding of novel shapes (Davidenko & Flusberg, 2013). Here we investigate the perception of analog clocks, another class of stimulus with a canonical upright orientation. In Experiment 1 we show that sitting participants indeed take longer to correctly tell time on rotated clocks as a monotonic function of the angular deviation from upright. In Experiment 2, we manipulated both the participants' position (0°–sitting up, +90°–lying right, and -90°–lying left) and the clocks' orientation (from -180° to +135°, in 45° increments) and measured response times to correctly tell time on the clocks. We found that both egocentric and environmental orientation influenced response times. By fitting a sinusoidal curve through the median response times, we estimated the "optimal" angle for perceiving clocks for each observer position. When subjects lay sideways, the optimal angle was approximately 30° away from egocentric upright (toward environmental upright). This finding extends our previous results and suggests that environmental orientation influences performance in a variety of visual tasks, indicating an important role for environmental orientation in visual encoding. Furthermore, our results inform the design of visual displays that will be viewed from non-canonical positions.

33.341 **Visual motion energy signal usage in gesture and speech integration: The role of semantic categorization and task demands** Bruce C Hansen[1](bchansen@colgate.edu), Spencer D Kelly[1], Pearce Decker[1,2], Rachel Weinstein[1], Stewart Lanphier[1]; [1]Department of Psychology and Neuroscience Program, Colgate University, Hamilton, NY, USA, [2]Brain Imaging and Modeling Section of NIDCD, National Institutes of Health, Bethesda, MD, USA

Hand gestures are pervasive with speech and greatly influence comprehension speed and memory of speech, leading some to claim that gesture and speech form an "integrated system" in language comprehension (e.g., Kelly, Özyürek, & Maris, 2010). Furthermore, gestures' facilitation of speech comprehension depends on which early visual spatial frequency (SF) channels (e.g., lower vs. higher SFs) carry the strongest motion energy signal (Kelly, Hansen, & Clark, 2012), and is therefore not exclusively tied to any particular SF band. Motivated by the latter, the present study draws on the flexible scale usage theory (e.g., Morrison & Schyns, 2001) to determine whether task-related semantic constraints can 'push' observers to differentially rely on motion energy in either low or high SFs. Stimuli consisted of 1sec co-speech gesture video clips. The spoken component conveyed either an action concept or an object concept that was either congruent or incongruent with the accompanying gesture. Participants engaged in one of two reaction time (RT) tasks that required either: 1) an explicit judgment regarding the congruency of the co-speech gestures, or 2) categorizing the spoken component of co-speech gestures as "action" or "object". The results showed that when the task required attending to speech and gesture (i.e., congruency judgment task), performance efficiency was regulated by high SF motion energy for object-oriented gestures, and low SF motion energy for action-oriented gestures. No such relationship was observed when participants were not required to attend to gesture (i.e., categorization task); although the RTs suggest that gestures did interfere with processing time on incongruent trials. In summary, co-speech gesture semantics can dictate SF motion energy utility, but only when gesture usage is obligatory. Curiously, when attention is directed away from vision, gestures still influence speech comprehension speed, suggesting that a visual signal other than SF motion energy is contributing to gesture-speech integration.

33.342 The Influence of Emotion on Audiovisual Integration in the McGurk Effect Theresa Cook[1](tcook002@ucr.edu), James Dias[1], Lawrence Rosenblum[1]; [1]University of California Riverside

In the McGurk Effect, cross-modally discrepant auditory and visual speech information is resolved into a unified percept. For example, the sound of a person articulating "ba" paired with a video display of a person articulating "ga," typically creates the heard percept "da." Furthermore, the McGurk Effect is robust to certain variables, including cross-modally incongruent gender and whether the stimuli are spoken or sung, but is affected by other variables, such as whether the audiovisually inconsistent phoneme creates a word or non-word. We tested the influence of emotion on the McGurk Effect. In Experiment 1, we recorded the audiovisual utterances of a model articulating /ba/, /da/, and /ga/ using happy, mad, sad, and neutral tones of voice and facial gestures. In experimental trials, auditory /ba/ was dubbed onto visual /ga/ to create McGurk stimuli typically heard as /da/. Emotion stimuli were included in the auditory channel, the visual channel, neither channel, or both channels. The comparison of interest was the strength of the McGurk effect between stimuli with and without emotion. Experiment 2 tested the strength of the McGurk Effect using the same stimuli as before, but with a reduction in available emotion information. We reduced visible emotion information by masking the visual stimuli so only the articulatory gestures of the mouth were visible. We found that the strength of the McGurk Effect is reduced by emotional expressions ($p < 0.001$). Furthermore, when we reduced the amount of visible emotion information in our stimuli in Experiment 2, the strength of the McGurk Effect was equivalent across all stimuli. Results may suggest that emotion information drains perceptual resources used in the audiovisual integration of speech. Findings will be discussed in light of the idea that the objects of perception in both cases may be the intended gestures of the communicator.

33.343 The texture of musical sounds: Cross-modal associations between visual textures and musical timbres and intervals Joshua Peterson[1](jpeterson@berkeley.edu), Thomas Langlois[2], Stephen Palmer[3]; [1]University of California, Berkeley, [2]University of California, Berkeley, [3]University of California, Berkeley

Previous research has provided evidence that cross-modal music-to-color associations are mediated by emotion, both for classical orchestral music (Palmer et al., 2013) and for a wide range of genres, from heavy-metal to Hindustani-sitar (Whiteford et al., VSS-2013). Similar results suggesting emotional mediation have been found using lower-level musical stimuli, including musical melodies (Palmer et al., VSS-2011) and two-note intervals and instrumental timbres (Griscom & Palmer, VSS-2012). Here we extended this line of investigation by studying musical associations to another salient visual domain: line-based geometrical textures. Using analogous experimental methods, we examined cross-modal associations from instrumental timbres and two-note musical intervals to visual textures consisting of many similar elements constructed from lines and/or curves. While listening to one of 16 instrumental timbres (flute, harpsichord, trombone, violin, etc.) or one of 12 two-note musical intervals (the tonic paired with the other 12 semitones in a full chromatic octave) participants chose the three most consistent and three least consistent visual textures from a 7x4 matrix of 28 black-and-white textures. Each subject later rated each timbre, interval, and texture individually on 13 dimensions: 5 emotional (e.g., happy/sad, angry/not-angry) and 8 geometric (e.g., sharp/smooth, simple/complex). For each dimension (e.g., happy/sad, sharp/smooth) we computed an index of timbre-texture associations (TTAs) and interval-texture associations (ITAs) as a weighted average of the (happy/sad) ratings of the 6 textures chosen as going best and worst with each timbre and each interval. We found strong correlations between ratings of the timbres and the TTAs of the textures chosen to go with them for some geometric and emotional dimensions (e.g., sharp/smooth=+.85, angry/not-angry=+.75). The same was true for two-note intervals for some dimensions (e.g., simple/complex=+.83; happy/sad=+.83). The results thus suggest that associations from low-level musical stimuli to visual textures may be mediated by corresponding dimensions in particular geometric and emotional qualities.

Acknowledgement: NSF

33.344 Clarifying the crossmodal Stroop effect in an auditory-visual colour naming task with words and non-words stimuli. Ding-Cheng Peng[1](pengding@myvuw.ac.nz), Steven L Prime[1]; [1]Neurocognition and Psychophysics lab, School of Psychology, Victoria University of Wellington

The majority of research on the Stroop Effect has been focused on studying the conflict of incongruent information within one sensory modality. Relatively little research has been done to investigate crossmodal conflict in a Stroop task. Most crossmodal Stroop studies have only looked at visual-auditory conflict in one direction, i.e., how auditory distractors interfere with identification of visual stimuli. How visual distractors (either colour words or patches) might interfere with colour naming of spoken words remains unclear. Here, we present two experiments that address this issue. In Experiment 1, subjects (n=16) performed two audio-visual Stroop tasks. In one task, they had to identify a colour patch that was accompanied by a spoken colour word (auditory distractor). In the other task they had to identify the spoken colour word whilst looking at a colour patch (visual distractor). Congruency of auditory and visual stimuli was varied. Distractor presentations varied from 500ms before to 500ms after target presentation to examine the relative time course of the crossmodal Stroop effects in these two tasks. Experiment 2 (n=16) was similar to Experiment 1 except the visual stimuli were written words of colours. Our main results show similar Stroop effects when subjects had to identify spoken words with both colour patch and written word distractors across the entire SOA range. Conversely, a Stroop effect for identifying visual stimuli only occurred when the spoken word distractor occurred at least 400ms before visual presentation. Our results are the first to show similar Stroop-like effects of written colour words and colour patches on spoken colour word identification indicating that the crossmodal Stroop effect between auditory and visual stimuli is not unidirectional in nature. The results also show visual distractors exert stronger crossmodal Stroop interference. These findings provide new insight into the problem of how stimulus compatibility affects crossmodal processing.

33.345 Bidirectional cross-modal synesthetic priming Chris Paffen[1](c.l.e.paffen@uu.nl), Maarten van der Smagt[1], Tanja Nijboer[1]; [1]Experimental Psychology, Utrecht University

For grapheme-color synesthetes, achromatic letters or digits appear to be inherently colored. This coupling between graphemes and colors has been suggested to be the result of hyperbinding, where synesthetes' cross-modal interactions are exaggerated compared to non-synesthetes. In the current study we used a priming paradigm in which primes and targets were presented to different sensory modalities (auditory and visual). In reaction time experiments, grapheme-color synesthetes and controls discriminated as fast and accurately as possible (1) the color of visual targets that were preceded by aurally presented digit primes, and (2) the identity of aurally presented digit targets that were preceded by visual color primes. The colors used were either congruent or incongruent to the synesthetic colors elicited by the digits used in the experiment. The results show that priming occurred bidirectionally across sensory modalities. When discriminating visual color targets preceded by aural digit primes, reaction times were longer when the color of the target was incongruent with the synesthetic percept reported (offline) for the prime. Likewise, when discriminating aurally presented digits targets preceded by visual color primes, reaction times were longer when the color of the prime was incongruent with the synesthetic percept for the target. These priming effects were absent in control subjects. Together, the results show that binding between graphemes and colors in grapheme-color synesthetes can occur bidirectionally across senses, thereby supporting the idea of hyperbinding in synesthetes. Moreover, they support the claim that, in spite of the explicit unidirectional nature, the coupling between grapheme and color in this form of synesthesia is bidirectional.

33.346 Synesthesia and Lateral Inhibition: A Case Study Diana Arias[1,2](dianajiab@gmail.com), Mathieu Simard[1,2], Dave Saint-Amour[1,2,3]; [1]Département de psychologie, Université du Québec à Montréal (UQÀM), , [2]Centre de recherche en neurosciences de l'UQÀM (NeuroQÀM), , [3]Centre Hospitalier Universitaire Sainte-Justine

Introduction: Synesthesia is a perceptual phenomenon when a stimulus in one sensory modality elicits an additional percept in the same or in another modality (e.g., when black letters and numbers are perceived as color graphemes or when sounds inducing color percepts).Although the underlying mechanisms of synesthesia are not known, it is largely thought that the synesthetic brain is characterized by a hyperconnectivity between different regions including the visual areas. Lateral inhibition (LI), which involves inhibitory local interactions between neighboring neurons in the visual brain, might be a new approach to explore the nature of the putative abnormal connectivity in synesthesia. Objective: The purpose of this study was to assess brain responses associated with lateral inhibition in synesthesia using scalp-recorded EEG. Methods: Steady-state visual evoked potentials (ssVEPs) were recorded from Oz in a color-grapheme synesthete female (27 years old) and in 12 control non-synesthetes using the windmill/dartboard paradigm (Zemon and Ratliff, PNAS, 1982). Stimuli consisted in four radial contiguous patterns, two static and two dynamic that were presented at a reversal-contrast frequency of 4.28 Hz and 30% contrast. Fast Fourier Transform (FFT) analysis was conducted to extract the fundamental and the second harmonic of ssVEPs in order

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to calculate the suppression and facilitation LI indices. Then, z-scores were computed for the synesthete subject in relation with the non-synesthete subjects. Results: No significant difference in the suppression or facilitation index was found. Conclusion: Lateral inhibition processing in the visual cortex is not abnormal in synesthesia. This case-study finding challenges the nature of the hyperconnectivity hypothesis in synesthesia.

Acknowledgement: Réseau de recherche de santé de la vision (visual research network)

33.347 **When "A" is not red but pink or yellow: How crossmodal and synaesthetic correspondences involve different cognitive strategies for non-synaesthetic French children** Marie-Margeride Garnier[1,2](marie.garnier2@univ-tlse2.fr), Jean-Michel Hupé[2], Michèle Guidetti[1]; [1]URI Octogone - EA4156 (Université de Toulouse, 31058 Toulouse), [2]CNRS CERCO UMR 5549 (Centre de Recherche Cerveau et Cognition, Université de Toulouse & Centre National de la Recherche Scientifique, 31300 Toulouse, France)

Recently, it has been suggested that synesthesia arises through mechanisms common to us all. Similarities were found between synesthesia and cross-modal correspondence; for instance, "A" tends to be red for both synesthetes and nonsynesthetes. Crossmodal and synesthetic correspondences could then be extremities of a single continuum. As adults, both synesthetes and non-synesthetes use cognitive strategies in colorletter pairing (e.g. based on order of elicitation or typicality of color terms). Synesthetic correspondences are created during childhood and are stable throughout life. If synesthesia really is an extreme form of the crossmodal correspondences found in the general population, we would expect non-synesthetic children to show signs of these cognitive strategies from an early stage, and for these strategies to be stable. Thus, the aim of this study was to test the continuum between crossmodal and synesthetic correspondences by investigating letter-color associations in non-synesthetic children ages 6, 7 and 8. Children had to write the entire alphabet in color. After 2-3 weeks they were given a surprise retest with the same instructions. Potential synesthetes (i.e. children that were more consistent over time than chance) were excluded from further analyses. We found that some pairings occurred more frequently than expected by chance, just as reported previously in adult synesthetes and non-synesthetes. However, unlike those studies, pairings differed across the 3 age groups and even changed within the same group from one session to the next. Furthermore, overall pairing patterns differed from those observed in English-speaking adults, and there were no correlations between these associations and any color or language regularity. Unlike synesthetic and non-synesthetic adults, children don't use cognitive strategies to pair colors with letters. Nonetheless, we noticed a tendency for children to change their associations across time to more closely resemble adults' associations. Cross-modal and synesthetic correspondences should therefore be studied separately.

33.348 **Two plus blue equals green: Grapheme-color synesthesia allows cognitive access to numerical information via color** J. Daniel McCarthy[1](mcdan27@gmail.com), Lianne N. Barnes[1], Bryan A. Alvarez[2], Gideon P. Caplovitz[1]; [1]Department of Psychology, University of Nevada, Reno, [2]Department of Psychology, University of California, Berkeley

In grapheme-color synesthesia, graphemes (e.g., numbers or letters) evoke color experiences. It is generally reported that the opposite is not true: colors will not generate experiences of graphemes or their associated information. However, recent research has provided evidence that colors can implicitly elicit symbolic representations of associated graphemes. Here, we examine if these representations can be cognitively accessed. Using a mathematical verification task replacing graphemes with color patches, we find that synesthetes can verify such problems with colors as accurately as with graphemes. Doing so, however, takes time: ~250 ms per color. Moreover, we find minimal reaction time switch-costs for switching between computing with graphemes and colors. This demonstrates that given specific task demands, synesthetes can cognitively access numerical information elicited by physical colors, and they do so as accurately as with graphemes. We discuss these results in the context of possible cognitive strategies used to access the information.

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Color and light: Surfaces and materials

Sunday, May 18, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

33.401 **Linking low-level and mid-level accounts of lightness perception** Alexandra Schmid[1](asch9222@uni.sydney.edu.au), Barton Anderson[1]; [1]School of Psychology, University of Sydney, NSW, Australia

We conducted a series of experiments to assess how the complexity of surface mesostructure and reflectance properties influence lightness judgments, and how these judgments provide insight into the computations and representations responsible for the perception of lightness in different classes of centre-surround displays. Methods. Flat, matte test patches embedded in 3D rocky surrounds (matte or glossy) were rendered in a natural illumination field. Experiment 1 evaluated the role of surface relief and gloss on perceived lightness, which was compared to two control displays that contained matched pixel histogram or an equated (phase-scramble) power spectrum. Experiment 2 evaluated whether transparency plays a role in the "crispening effect" observed with the homogeneous surrounds. Observers adjusted the lightness and transmittance of a match patch, but were given either mid-level (transparency) or low-level (contrast) task instructions. Experiment 3 used the matches from the second experiment to create stimuli for a 2AFC paired comparison task where observers selected the stimuli which best matched the lightness of the uniform displays. Results. Experiment 1 showed that both surface relief and gloss improved lightness constancy, but the results were indistinguishable from the displays with equated power spectrums. Experiment 2 revealed that observers only varied transmittance when instructed to equate match patch contrast, not when directed to equate transparency and lightness. The results of Experiment 3 revealed the transparent match pattern under the contrast matching instructions generated the best overall lightness matches. Conclusions. For complex displays, the effects of surface mesostructure and surface optics are well explained by "low level" distributions of contrasts across space and scale. Homogeneous displays are paradoxically complex: although they are best matched with transparent stimuli, observers do not appear to have direct phenomenal access to the qualities of the transparent representation, and can only achieve these matches by relying on local contrast cues.

Acknowledgement: Australian Research Council

33.402 **Surface roughness increases ability to distinguish gloss from matte.** Shinho Cho[1](choxx305@umn.edu), Daniel Kersten[1]; [1]Department of Psychology, University of Minnesota

It has been shown that human perception of surface gloss depends on the correspondence between specular highlights and the underlying surface shading. However, it is not known how gloss perception might depend on surface roughness. Increased roughness could increase the perceptual evidence in support of a gloss interpretation. Alternatively, roughness may increase the computational demand on estimating detailed shape from the underlying surface shading, resulting in a loss of correspondence information. We measured how human judgments of glossiness depend on surface roughness as a function of the spatial congruence between matte shading and specular highlights. We simulated surfaces of varying roughness by modulating depth according to a random Brownian process. We then manipulated the perceived gloss by rendering separate matte and gloss image layers, and combining these layers with various spatial displacements (Anderson & Kim, 2009). Subjects performed a 2AFC comparison task in which they indicated which of two surfaces looks glossier. Consistent with previous results, we found that the discriminability of gloss dropped as a function of the congruence between the gloss and matte layers. In addition, we found that the ability to distinguish gloss from matte increased with surface roughness, supporting the idea that increased evidence for correspondence improves gloss perception

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33.403 **Perceiving gloss in surfaces and images** James Ferwerda[1](jaf@cis.rit.edu), Adria Fores[2], Ingeborg Tastl[3], John Recker[3]; [1]Chester F. Carlson Center for Imaging Science, Rochester Institute of Technology, [2]Program of Color Science, Rochester Institute of Technology, [3]Hewlett-Packard Laboratories

We create images as a means to record and communicate object appearance, and it is self evident that images are generally effective for this purpose. However looking at an image of an object is not the same as looking at the object itself due in part to the technological limitations of imaging devices and media such as resolution and dynamic range. In this project we

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investigated how well computer-generated images represent the appearance properties of real glossy objects. We started by creating an ordered set of printed gloss samples using a commercial-grade HP Indigo electrostatic printer that can selectively apply matteing layers on top of the colored toners. We then measured the set to determine the bi-directional reflectance distribution functions (BRDFs) of each sample. Next we modeled those BRDFs, and used advanced physically-based rendering techniques to render images of the samples as cylinders in a virtual light booth with an area light source and checkerboard-patterned walls. At the same time, we built a matching physical lightbooth and also created a matching physical sample set by wrapping the original paper samples around plastic cylinders. We then conducted a series of scaling experiments in which we had subjects perform both within and across media matching tasks (real-to-real, image-to-image, image-to-real). The results show that on average, observers are capable of performing the matching task in all three conditions, but that there are significant differences in sensitivity to gloss differences across the three conditions, with real-to-real matching showing the highest sensitivity and cross-media image-to-real matching showing the lowest. This work contributes to our understanding of both gloss perception and image perception, and is part of an ongoing effort to understand how and how well images serve as visual representations of objects and surfaces.

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33.404 Lack of glossiness constancy with viewpoint changes

Sabrina Hansmann-Roth[1], Pascal Mamassian[1]; [1]Laboratoire des Systèmes Perceptifs (CNRS), Ecole Normale Supérieure, 29 rue d'Ulm, 75005 Paris, France

The presence of a bright, specular highlight is one of the most important factors in gloss perception. Previous work has shown that even when highlights cover only a small region on a surface, they lead to the impression that an object has a uniform surface material (Beck 1981, Percept. Psychophys.). In the present study we investigate whether perceived glossiness changes depending on the observers' viewpoint. A single, large, mostly fronto-parallel surface was cut in 49 parts and each part was presented one at a time. The surface contained periodic structural elements in relief so that each part included the same structures but at different spatial locations. Each resulting stimulus image had a 50 % overlap with the neighboring image. The participant's task was to compare the presented stimulus image with 7 calibrated probe images and select the probe that had the most similar gloss to the stimulus. Each stimulus was presented for 2 s at the spatially correct position on the computer monitor. Our results indicate that perceived glossiness changes over the surface. From the data we computed a glossiness map that corresponds to the mean glossiness ratings for each part of the surface. Glossiness ratings varied over the surface indicating that gloss is not perceived equally on the surface. Since all stimuli were part of one periodic image, light source and 3D geometry were identical, however the viewing direction was different for each point on the surface. Therefore highlight-structure varies at different parts of the surface. Controlled experiments were run to test whether these changes in highlight shape and size were interpreted as changes in the material properties and not as an artifact produced by the viewing direction or other change that occurs with a different viewing direction. In summary, gloss constancy does not seem to occur with viewpoint changes.

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33.405 Correlation of gold appearance with surface metallicity and glossiness

Tomohisa Matsumoto[1](matsumoto@u.ip.titech.ac.jp), Kazuho Fukuda[1], Keiji Uchikawa[1]; [1]Department of Information Processing, Tokyo Institute of Technology

Gold is perceived in glossy surfaces with certain chromaticity ranges. Appearance of gold positively correlates with perceived glossiness (Matsumoto et al., APCV 2011) and also with the surface metallicity (Matsumoto et al., APCV 2012). These previous findings suggest that the visual system utilizes the chromaticity and glossiness or the metallicity of surface to perceive gold. Glossy plastic does not appear gold, which means that gold is perceived not based on glossiness only, but to some extent based on the factor that yields the surface metallicity. In the present study, we investigated the relation between perceptual degree of goldenness, the surface metallicity and glossiness in order to understand the perceptual mechanism for gold. We simulated metallic and non-metallic objects (sphere, Stanford Bunny and 26-faceted polyhedron) with 3DCG as stimuli in our experiments. The intensity of metallic and non-metallic images was morphed to make stimuli with different metallic levels (6 levels). The intensity of each morphed image was multiplied to be different in luminance levels (5 levels). The same chromaticity, which was obtained to make high degree of goldenness in our previous experiments, was used for all images. The observer performed the magnitude estimation of goldenness, the surface metallicity and glossiness. Our results show that when the surfaces were estimated somewhat golden, they were always evaluated as metallic. On the other hand, when the surfaces were evaluated as non-metallic but somewhat glossy, they were hardly rated with goldenness. These results indicate that perception of metallic surface is necessary for perception of gold. Moreover, as a result of partial correlation analysis, we found that the degree of goldenness positively correlated with the surface metallicity, but mostly not with glossiness. It is suggested that gold is perceived based on the factor in perceiving of the surface metallicity instead of glossiness.

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33.406 The Perception of Glossiness in the Human Brain

Hua-Chun Sun[1](hxs195@bham.ac.uk), Hiroshi Ban[2], Andrew Welchman[3]; [1]School of Psychology, University of Birmingham, [2]Center for Information and Neural Networks, National Institute of Information and Communications Technology, [3]Department of Psychology, University of Cambridge

The impression of surface gloss defines important properties of objects that can influence diverse behaviors. Recent progress has been made in understanding the monkey cortical areas that respond to gloss (Nishio, et al., 2012; Okazawa, et al., 2012), however, the network of areas in the human brain remains unclear. We used fMRI measurements to localize brain areas preferentially responding to glossy objects. We used Blender to render 32 nonsense objects as either Lambertian or having a specular component to their surfaces. We used spatially scrambled versions of the stimuli to control for low-level image differences. This scrambling was based on superimposing a grid over the images and then randomly relocating squares from within the grid. There were four conditions: glossy, scrambled glossy, matte and scrambled matte. Fifteen participants took part in a block-designed fMRI session and performed 1-back matching task on the images. Functional MRI activations were measured over the whole brain with echo-planar imaging (EPI) sequence (32 slices, TR 2000 ms, TE 35 ms, voxel size 2.5 × 2.5 × 3 mm) and a 32-channel head coil. We analyzed the data using a general linear model (GLM). We found that activations related to gloss were mainly observed along ventral visual areas in both hemispheres. Activations in fusiform gyrus (FG), collateral sulcus (CoS) and kinetic-occipital (KO) region were significantly stronger in glossy condition than the other three conditions, suggesting a preference for glossy surfaces. These areas are consistent with previous reports of activity in the FG and CoS related to the perception of object material properties (Cant, et al., 2009; Cant & Goodale, 2007; Hiramatsu, et al., 2011). Thus, our results suggest a small network of ventral areas whose activity may be important in supporting our perception of material properties in general, and surface gloss in particular.

33.407 Visual perception of fluid viscosity over time

Jan Jaap R. van Assen[1](janjaap.vanassen@gmail.com), Vivian C. Paulun[1], Roland W. Fleming[1]; [1]Department of Experimental Psychology, University of Giessen, Germany

In everyday life, we usually have no problem distinguishing liquids with different viscosities, such as water, honey and tar. However, it is not known exactly how we achieve this and which image measurements have most influence on our perception of viscosity. Here, we investigated how stable visual estimates of viscosity are over time, as liquids pour continuously into a container. This allows us to test the extent to which the visual system can extract properties of the shape and motion of the liquid that are invariant across its volume and previous history, a basic requirement for achieving 'viscosity constancy'. We simulated seven liquids with different viscosities, ranging from highly viscous gel-like fluids to runny water-like fluids, and selected seven time frames from the animations that contained perceptually salient events (e.g. splash events). These static images were selected based on pilot studies in which subjects indicated the most informative frames from the animation. The scene consisted of a fluid source, a fixed solid sphere and an invisible reservoir, which filled up over time as the volume of the fluid increased. On each trial, the observers were presented with a static frame at a given time point from one of the seven viscosities, and had to indicate which of seven frames from a standard time point had the corresponding viscosity in a 7AFC paradigm. Thus, subjects had to identify viscosity based on static shape cues, across differences in time. The results show that subjects make systematic errors across all stimuli, although accuracy increases over time. The pattern of errors suggests that subjects rely on a number of simple shape-based heuristics to perform the matching task, which leads to performance that is substantially below 'viscosity constancy'.

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33.408 Qualities of optically mixed real materials and photographs – towards a material probe Sylvia Pont[1](s.c.pont@tudelft.nl), Susan te Pas[2], Maarten Wijntjes[1]; [1]Perceptual Intelligence lab, Industrial Design Engineering, Delft University of Technology, [2]Faculty of Social and Behavioural Sciences, Utrecht university

Natural materials cover a wide range of surface scattering properties, which can be described by the bidirectional reflectance distribution function (BRDF). The lobes of the BRDF may be described by their primary scattering direction (resulting in salient features of the appearance modes at different locations) and generic BRDFs typically consist of several of such lobes. Thus, similarly to describing BRDFs as linear superpositions of scattering lobes, we can describe the appearance of objects consisting of any materials as linear superpositions of objects of different canonical materials. We approach this problem via optically mixing of objects that represent canonical reflectance modes, allowing systematical and gradual variations of materials to test perceptual qualities of generic materials. We performed two experiments with a shiny, matte and velvety green bird, representing the forward, diffuse and surface scattering modes. The mixing was done with combinations of two materials in a real setup, using a semi-transparent mirror, and with combinations of three materials on a screen, using superpositions of photographs. In both experiments we tested how observers rated glossiness, softness, warmth and heaviness for systematically varied weights of the materials combinations. Finally we conducted a survey about how observers experienced the optical mixtures. We found systematical, gradual variations of the ratings as a function of the weightings, for the real stimuli consisting of dual mixes and for the images consisting of triple mixes. The data patterns for the real stimuli and for the images were consistent with each other for glossiness, softness and warmth ratings, but showed a global scaling and slight local modulation for heaviness. Observers thought we were varying material, lighting and color and they found the birds to look real. These results show that we can use optical mixtures as a basis for a material probe to investigate perception of generic, real materials.

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33.409 Discrimination of highlights from reflectance changes using isophote maps of surface images Masataka Sawayama[1](masa.sawayama@gmail.com), Shin'ya Nishida[1]; [1]NTT Communication Science Laboratories, Nippon Telegram and Telephone Cooperation, Japan

Low-level image statistics such as skewness of luminance/subband histogram are effective cues for surface gloss perception (Motoyoshi, Nishida, Sharan & Adelson, 2007). Nevertheless, these statistics alone cannot explain why specular highlights look more like white blobs produced by surface reflectance changes when the highlights are inconsistent in position and/or orientation with the diffuse shading component (Marlow, Kim & Anderson, 2011). Here we show that specular-shading consistency can be judged by 2D image inspection without referring to the 3D shape or illumination of the surface. A surface image can be decomposed into reflectance, shading and specular images. Whereas the reflectance image is independent of the shading image, the specular image is dependent on the shading image, because the shading intensity is a function of the incident angle of light, while the specular intensity is a function of the incident and viewing angles of the light. As a result, within each highlight region, the surface normal directions are nearly uniform, and so are the shading intensities. Diffuse components under and around veridical highlights should have similar intensities. Violation of this constraint implies a reflectance change, and this can be checked with isophote maps. We made consistent-glossy or inconsistent-blobby images by combining specular and diffuse patterns, rendered from the same or uncorrelated depth profile, respectively. The image analyses showed that for consistent images, addition of the specular component affected little the isophote-contours of the original matte image. For inconsistent images, on the other hand, addition of the specular component significantly altered the isophote-contours of the matte image. This explains why a histogram change can perceptually erase highlights in the consistent images (i.e., making them natural pure matte images), but not white blobs in the inconsistent image. These observations suggest that isophote maps contain useful 2D information for discrimination of highlights from white blobs.

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33.410 Material Perception in Blind and Sighted Participants Elisabeth Baumgartner[1](baumgartnerelisabeth@gmail.com), Christiane Wiebel[1], Karl Gegenfurtner[1]; [1]Abteilung Allgemeine Psychologie, Justus-Liebig-Universität Gießen

Both the visual and the haptic senses play important roles in the everyday perception of materials. However, how the two senses compare in material perception tasks and how they influence each other in the emergence of a common representation of materials is largely unknown. We have recently compared material property ratings following visual exploration of materials with ratings following haptic exploration and found that participants' judgments of material properties are very similar, independent of the type of exploration (Baumgartner, Wiebel, & Gegenfurtner, 2013). However, when we asked our observers to categorize the different material samples, their performance was better with visual exploration rather than haptic exploration. To explore the effect visual experience has on material perception, we asked congenitally blind participants to explore different materials haptically and rate several material properties (roughness, elasticity, hardness, three-dimensionality, friction, orderliness, and temperature). In addition, we asked them to categorize our materials into one of eight categories (plastic, paper, fabric, fur, leather, stone, metal, and wood). Principal components analyses were conducted on sighted participants' haptic rating data as well as blind participants' haptic rating data. A procrustes analysis showed that the two principal component spaces were highly similar. Categorization performance was also comparable for the two groups. (sighted participants: 66.6%, congenitally blind participants: 68.6%). We conclude that the representational space of materials we have observed can be formed without the influence of visual experience.

33.411 Colorimetric Analysis of Makeup Styles and Their Relation with Visual Quality Perception of the Skin Carlos ArceLopera[1,2](arcelopera.carlos@gmail.com), Takanori Igarashi[3], Katsunori Okajima[2]; [1]ICESI University, [2]Yokohama National University, [3]Kao Corporation

Skin quality perception is a discrimination process that determines many of our attitudes towards a person. However, the perception mechanisms involved in this process are not fully understood. Vision-based approaches can contribute to understand the role of human vision perception when confronted to visual quality estimation of complex materials such as the human skin. Here, we analysed how the colorimetric changes affected the visual perceived quality of human skin when modified by different makeup styles. A makeup artist was given the task to created 4 different makeup styles based on four given keywords: flat, fluffy, wet and sharp. The makeup was applied to the same woman on the same day. First, we took photographs of each makeup style in a controlled environment. Then, we randomly presented these images to subjects that judged the visual quality of the skin. The experimental results revealed that the applied makeup styles had different degrees of quality perceptions enabling their use in quality discrimination experiments. Moreover, the results were correlated with luminance statistics for the visibility of pores and glossiness perception. However, the visibility of makeup was uncorrelated with luminance statistics. Furthermore, we created artificial stimuli with only variations in their luminance distribution and without any change in the chromatic information. When presenting the artificial stimuli, the experimental results showed that the perceived quality of the skin changed, supporting the hypothesis that luminance distribution plays an important role as a visual cue for the determination of visual quality of human skin texture. Our results complement previous research findings, and open the possibility for the creation of new automated cosmetic efficacy estimators. Moreover, the development of cosmetics focusing on the luminance distribution of the skin can represent new alternatives for foundations that keep the original color of the skin and therefore give a more natural impression.

33.412 Color Flows and Color Mixing Daniel Holtmann-Rice[1](daniel.holtmann-rice@yale.edu), Steven Zucker[1]; [1]Computer Science, Yale University

In recent work, we demonstrated a strong interaction between color flows and luminance flows in the perception of complex shaded surfaces: When shading spatially covaries with spectral information, the shape from shading percept is strongly suppressed (an example of the color-shading effect). In explaining this phenomenon, we suggested a role for double-opponent orientation-selective operators. These operators can be interpreted as signaling spatial derivative information in the red-green and blue-yellow chromatic planes. Here we investigate the conditions under which these red-green and blue-yellow double-opponent flows align in orientation. We demonstrate theoretically that this alignment occurs when gradients of hue and chroma are themselves locally aligned. In this case, the double-opponent operators signal directions of constant hue ("iso-hue"). This situation arises

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for example in mixing between two colors, e.g., along a gradient. However, we show that the flows generically diverge when mixing between three or more color sources: In this case, directions of iso-hue and iso-chroma emerge as linear combinations of iso-RG and iso-BY directions. These observations facilitate the construction of stimuli that can identify whether directions of iso-hue play a causal role in the color-shading effect, or whether the effect can be explained solely in terms of covariation between red-green or blue-yellow double-opponent flows and the shading isophote structure.

33.413 **The perception of surface gray shades and the computational goals of human vision** Tony Vladusich[1,2](therealrealvlad@gmail.com), Mark McDonnell[1]; [1]Institute for Telecommunications Research, University of South Australia, Australia, [2]Center for Computational Neuroscience and Neural Technology, Boston University, USA

Classical theories of the perception of surface gray shades propose that a key computational goal of human vision is to mathematically 'invert' the physical processes of light reflection from surfaces (e.g. that create shadows and highlights) and light transmission through atmospheric media (e.g. due to fog or smoke) to recover surface reflectance. Yet the computational goal of recovering surface reflectance is extremely difficult to accomplish, incompatible with key perceptual data on the distinction between 'brightness' (luminance) and 'lightness' (reflectance) perception, and does not necessarily solve other important computational problems, such as how the visual system computes 'perceptual layers' corresponding to physical surfaces, illumination, and atmospheric media. Here we present a model, based on a recently introduced theory of surface perception, which suggests that the characteristic properties of surface gray-shade perception are better explained in terms of the computational goal of parsing the retinal image into perceptual layers, rather than in terms of the goal of recovering surface reflectance. The model explains some striking demonstrations of surface gray-shade perception through transparent overlays, quantitatively predicts key perceptual data on brightness/lightness perception, and conceptually unifies the prominent anchoring and scission theories of surface perception. The model thus suggests that a detailed understanding of human vision may require a subtle reformulation of the computational problems solved by the visual system.

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33.414 **Color categorization of natural objects** Zarko Milojevic[1](Zarko.Milojevic@psychol.uni-giessen.de), Robert Ennis[1], Karl Gegenfurtner[1]; [1]Department of Psychology, Justus Liebig University Giessen

Individuals can give a single color name to a natural object, even though these objects often have color variations across their surfaces. However, it is unclear how observers exploit the information in natural objects to give them a single color name. Since autumn leaves have varying color distributions, we instructed 8 naive observers to assign color names to photographed autumn leaves. Observers viewed high-resolution, 16-bit photographs (constant focus, camera distance, and background conditions with a D65 illuminant) of 275 leaves that ranged from pure "red" to pure "green". Observers indicated whether each leaf appeared "red" or "green" with two buttons. The leaves in each photo were segmented from the background and converted to their corresponding DKL coordinates. Each leaf's isoluminant color distribution mostly resided in the lower right quadrant of the isoluminant plane (the "red-yellow" quadrant). In particular, leaves that appeared "green" had color distributions close to and extended along the "Yellow" direction, with little distribution along the "Green" direction. Various statistics were computed for the isoluminant color distributions (mean, standard deviation, number of "red"/"green"/"yellow" pixels). To find the most informative statistics, linear classifiers were trained on every combination of these statistics, using a "leave-one-out" method: cycle through observers, use the other observers' data for training, and then use the trained classifier to predict the excluded observer's categorizations. For each leaf, the most frequent color name assigned by observers in the training set was taken as "ground truth". On average, the mean color predicts 92% of observer's classifications, explaining most of the variance. Including the standard deviations of each leaf's color distribution along the R-G and Y-V cardinal axes, as well as the number of "red"/"green"/"yellow" pixels, marginally improves the average prediction rate to 93%. Thus, when assigning color names to objects, observers might give little weight to spatial structure.

33.415 **Perception of saturation in natural scenes** Florian Schiller[1](Florian.Schiller@psychol.uni-giessen.de), Karl Gegenfurtner[1]; [1]Department of Psychology, Justus-Liebig-University Giessen

For most color spaces, there is at least one measure for determining the saturation of a color. It is unclear, how well these different measures correspond to human perception. We conducted two experiments in an attempt to fill this gap. We chose 80 color images of natural scenes from the categories "flowers", "man-made", "foliage", and "land-water" from the McGill database of calibrated color images. The images were shown to 8 participants in full color and to another 8 participants in grayscale on a calibrated LCD monitor in randomized order. Participants were asked to select the pixel in the image that appeared to be the most saturated with a mouse cursor. We compared the judgments of the participants to different measures of saturation defined in the DKL, LAB, LUV, and xyY color spaces. We also used saturation from the HSV color space and a measure defined by Koenderink. Our results show that all of the measures capture saturation quite well. The pixels chosen by the participants from the color images were amongst the top 20% saturated pixels for all of the measures, and amongst the top 10% when a small degree of spatial uncertainty with respect to the chosen pixel was allowed. When confronted with the grayscale images, participants were still able to pick pixels whose counterparts in the color images were rated as more saturated by the six measures than randomly selected pixels. Our results indicate that saturation in natural scenes can be specified quite well even without taking image structure into account. Participants are able to infer saturation from the grayscale images from features correlated with color saturation or using prior knowledge in order to make their judgments.

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Motion Perception: Models

Sunday, May 18, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

33.416 **Motions of Parts and Wholes: An Exogenous Reference-Frame Model of Non-Retinotopic Processing** Aaron Clarke[1](aaron.clarke@epfl.ch), Haluk Öğmen[2], Michael Herzog[1]; [1]BMI, SV, ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE (EPFL), [2]Dept. of Electrical & Computer Engineering, University of Houston

Object parts are seen relative to their object. For example, the reflector on a moving bicycle wheel appears to follow a circular path orbiting the wheel's center. It is almost impossible to perceive the reflector's "true" retinotopic motion, which is a cycloid. The visual system discounts the bicycle motion from the reflector motion in a similar way to how eye movements are discounted from saccadic shifts. With reflectors, however, no efference copy is available. In addition, the visual system needs to create an exogenous reference-frame for each bicycle. Relativity of motion cannot easily be explained by classical motion models because they can only pick out retinotopic motion. Here, we show how a two-stage model, based on vector fields, can explain relativity of motion. The image is first segmented into objects and their parts (e.g. bicycles, reflectors, etc.) using association fields. Motion is computed for each object (e.g., bicycle and reflector motions) using standard motion detectors. Ambiguous correspondence matches are resolved using an autoassociative neural network (Dawson, 1991). Next, the motion vectors are grouped into local manifolds using grouping cues such as proximity and common fate (resulting in all the motion vectors from one bicycle and its parts being grouped together). Within each group, the common motion vector is, then, subtracted from the individual motion vectors (e.g., the bicycle motion is subtracted from the motion of its reflectors). Thus, the model tracks the bicycle and its reflectors across time, discounting for the bicycle's overall motion. We test our model on several benchmarks, including the non-retinotopic motion perception in the Ternus-Pikler Display. Our model clearly outperforms all past models that either lack image segmentation or that apply only a single spatio-temporal filtering stage and thus fail to put object parts into a motion-based exogenous reference frame.

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33.417 **Influence of Correspondence Noise on Dmax for Low Coherence Random-dot Kinematogram Stimuli** Srimant Tripathy[1](s.p.tripathy@bradford.ac.uk), Syed Shafiullah[1], Michael Cox[1]; [1]School of Optometry & Vision Science, University of Bradford

Correspondence noise is a major factor limiting performance for detecting motion in random-dot kinematogram stimili, whether performance is measured as threshold coherence (Barlow, H.B. & Tripathy, S.P., Journal of Neuroscience, 17, 7954-7966, 1997) or as the upper limit for spatial displacement (Dmax) in fully-coherent two-frame kinematograms (Tripathy, S.P., Shafiullah, S.N. & Cox, M.J., PLOS ONE, 7:10, article e42995, 2012). The current study extends the earlier Dmax study to stimuli with low coherence-levels (approximately 30% coherence). Psychophysics: The dot density of 2-frame kinematograms was varied over the range 0.1-26.7 dots/deg2. For each tested dot-density in this range, dot displacement was varied and performance was measured as the proportion of trials with direction (left/right) of motion correctly identified. Dmax was the dot displacement that yielded 75% correct direction identification. Averaged over three observers, Dmax ranged from 42 arcmin at the lowest dot-density to 32 arcmin at the highest dot-density. Modelling: The stimuli used for the psychophysical experiments were presented to a model consisting of Reichardt detectors that randomly tiled the stimulus plane. The radius of the two catchment areas of each detector were scaled with the size of dot-displacement in the stimulus (Tripathy et al, 2012).In the earlier study a single scaling factor could account for Dmax across the range of dot densities tested using 100% coherent stimuli. In contrast, when the coherence level was 30%, the scaling factor was found to decrease monotonically with dot density.Conclusion: The results suggested that when stimuli were noisy, either the catchment areas of the motion detectors shrank monotonically, or the motion detecting system relied on a different set of smaller detectors, as dot density increased. These results complement recent physiological findings that adding visual noise causes the receptive fields of macaque MT neurons to shrink (e.g. Kumano, H. & Uka, T. Journal of Neurophysiology, 108, 215-226, 2012).

33.418 Adaptive shifts of spatiotemporal contrast sensitivity function: context adaptation vs. point adaptation

Ambarish Pawar[1](ambarish@salk.edu), Thomas Albright[1], Sergei Gepshtein[1]; [1]Salk Institute for Biological Studies

Adaptation is expected to improve visual performance for prevailing stimuli. Previous studies yielded conflicting results: no change (Barlow, MacLeod & van Meeteren, 1976), gain (Clifford & Wenderoth, 1999), or loss (DeValois, 1977) of sensitivity at the adapting conditions, or change of sensitivity to stimuli vastly different from the adapting conditions (DeValois, 1977; Krekelberg, van Wezel & Albright, 2006). Many of the inconsistencies are resolved, however, when effects of adaptation are studied comprehensively, across the entire range of visible spatiotemporal stimuli: the domain of the spatiotemporal contrast sensitivity function (CSF; Kelly, 1979). A characteristic pattern of local gains and losses of sensitivity is consistent with a global shift of CSF, predicted by a theory of efficient allocation of receptive fields (Gepshtein, Lesmes & Albright, 2013). In the latter study, adaptation was instantiated by varying the distribution of stimuli across trials, so that different distributions of stimulus speeds on different days created a change of stimulus statistics: high-speed and low-speed stimulus contexts ("context adaptation"). This is in contrast to the single adapter typically used in previous studies ("point adaptation"). Does the systematic global pattern of sensitivity changes observed in context adaptation generalize to point adaptation? We measured a "slice" of CSF at six spatial frequencies (between 0.2 and 8 c/deg) at the same temporal frequency (0.5 Hz) using a direction discrimination task. On every trial, the stimulus was preceded by a static or dynamic high-contrast "point adapter" at the same spatial frequency within an experiment. In all conditions and observers, the contrast sensitivity was suppressed by adaptation. But the peak of CSF shifted away from the adapting spatial frequency for both static and dynamic point adapters, consistent with the notion that adaptation generally causes global shifts of CSF.

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33.419 Dissecting the oblique effect: Replicating the expansion of motion direction space around the cardinal axes with a computer model built from V1 and MT neuron inputs

John Perrone[1](jpnz@waikato.ac.nz), Dorion Liston[2,3], Leland Stone[3]; [1]University of Waikato, [2]San Jose State University, [3]NASA Ames Research Center

Direction discrimination thresholds are higher for motion along diagonal directions than for motion along cardinal directions. This has been shown both for human psychophysics and smooth pursuit (e.g., Krukowski & Stone, Neuron, 2005). The physiological mechanism underlying this 'oblique effect' remains unknown. Given the increasing use of 'oculometric' measures of motion perception (Stone et al., Perception and Eye Movements. In: Encyclopedia of Neuroscience, 2009), it would be useful to isolate the motion processing stage at which these perceptual and oculomotor direction biases arise. To this end, we tested whether elements of a model of visual motion processing based on V1 and Middle Temporal (MT) neurons (Perrone, JOV, 2012) could replicate the oblique effect. The input stimuli consisted of 128 x 128 pixel x 8 frame movies of a moving dot. We ran 50 trials at each of 5 dot direction angles (A ± 4° and ± 8°) where A = 90° (cardinal) or 135° (oblique). The final model output was derived from the weighted vector average of the individual local velocity vector estimates generated at frame 4 of the output. A linear regression of actual versus estimated direction produced a slope of 1.8 for the cardinal test and 0.6 for the oblique, thus replicating the typical empirical data pattern of higher gain for the cardinal versus oblique directions (Krukowski & Stone, 2005). In the model, systematic amplifications of direction space arise from the inhibitory mechanism used by Perrone (JOV, 2012, Fig. 9) to prune the direction of velocity outputs arising from the MT pattern units to some extent. These 'spurious' directional signals are inhibited by a signal from MT component units at the same location as the pattern units, before the output is fed into the velocity sensors. When this inhibitory signal was turned off in the model, the oblique effect disappeared.

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33.420 A Counterchange-based Dynamic Neural Network for Solving the Correspondence Problem

Joseph Norman[1](jnorman@ccs.fau.edu); [1]Center for Complex Systems and Brain Sciences, Charles E. Schmidt College of Science, Florida Atlantic University

The correspondence problem arises when multiple visual elements are discretely displaced leading to perceptual ambiguities in terms of 'what moved where'. Elements are sometimes seen to originate or terminate at a common location (splitting or fusing, respectively), while other times not. A hard constraint is proposed to account for the visual system's solution to an array of correspondence displays: a motion path may not participate in both a split and a fusion; this is termed the unique split/fusion principle. The combined application of this principle and the differential activation principle (shorter-path motions are more strongly activated than longer-path motions [Gilroy, Hock & Ploeger, 2001]) accounts for solutions to novel and benchmark correspondence displays. A continuous-time dynamic neural network is implemented to embody the proposed principles. Motion detection is achieved via a counterchange detection mechanism (motion is signaled from a location of decreasing spatial filter activation to a location of increasing spatial filter activation). Motion signals are selected for (and against) via cooperative inhibition in which multiple independent motion paths (i.e. paths that do not share an origin or a termination) multiplicatively co-inhibit mutually dependent motion paths (i.e. paths that share an origin or a termination). In addition to accounting for a wider range of correspondence solutions, previously proposed correspondence principles (e.g. relative velocity and element integrity [Dawson, 1991], cross-direction inhibition [Hock, Schöner, Brownlow & Taler, 2011], good cover [Ullman, 1979]) are shown to emerge from the dynamic neural network.

33.421 Optimal tracking model accounts for perceptual conflict between motion and position in the curveball illusion

Oh-sang Kwon[1](oskwon@cvs.rochester.edu), Duje Tadin[1,2], David Knill[1]; [1]Center for Visual Science & Dept. of Brain and Cognitive Sciences, University of Rochester, [2]Department of Ophthalmology, University of Rochester

We have previously shown that an optimal object tracking model accounts for the well-known illusory motion-induced position shift (in which the position of a stationary envelope that contains a moving pattern is shifted in the direction of pattern motion). The model works by optimally using noisy sensory signals to estimate both the motion of the object containing a pattern and the motion of the pattern within the object (VSS 2013). The model makes the novel prediction that when the pattern motion within an envelope differs from the motion of the envelope one's percept of object motion should conflict with temporal changes in one's percept of object position. METHODS: To measure both perceived position and perceived motion of an object, we adapted the well-known 'curveball illusion' stimulus. In this illusion, an object moves downward, while the pattern within the object moves horizontally. In peripheral vision (11°), the object appears to move obliquely. We measured subjects' perceived object position and motion direction for different stimulus durations (20-400 ms). In position blocks, subjects reported the final perceived object position. In motion blocks, subjects reported the final object motion direction. RESULTS: Subjects' horizontal object position biases initially increased with stimulus duration, but asymptoted after 200 ms. (suggesting a constant estimate of horizontal position after 200 msec.) In contrast, their perceived object motion trajectory was oblique at all durations, indicating a non-zero percept of the object's horizontal component of motion. While seemingly irrational, this conflict is consistent with the prediction of the optimal tacking model.

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33.422 **Motion-based prediction model for flash lag effect** Mina A Khoei[1,2](mina.aliakbari-khoei@univ-amu.fr), Laurent U Perrinet[1,2], Guillaume S Masson[1,2]; [1]Institut des Neurosciences de la Timone (INT), UMR7289, CNRS, Marseille, France, [2]Aix Marseille université

The flash lag effect (FLE) is a well known visual illusion that reveals the perceptual difference in position coding of moving and stationary flashed objects. It has been reproduced experimentally in retina and V1 along with some relevant evidences about motion based position coding in areas MT and MT+. Numerous hypotheses for mechanisms underlying FLE such as motion extrapolation, latency difference, position persistence, temporal averaging and postdiction have been under debate for last two decades. Here, we have challenged our previous motion-based prediction model to understand FLE, consistently with the motion extrapolation account proposed by Nijhawan. Our hypothesis is based on predictability of motion trajectory and importance of motion signal in manipulation of receptive field shape for moving objects. Using a probabilistic framework, we have implemented motion-based prediction (MBP) and simulated three different demonstrations of FLE including standard, flash initiated and flash terminated cycles. This method allowed us to compare the shape of the characteristic receptive fields for moving and stationary flashed dots in the case of rightward and leftward motions. As control model, we have eliminated velocity signal from motion estimation and simulated position-based (PX) model of FLE. Results of MBP model suggest that above a minimal time for duration of flash, the development of predictive component for the moving object is sufficient to shift in the direction of motion and to produce flash lag effect. MBP model reproduces experimental data of FLE and its dependence to the contrast of flash. Against what has been argued as shortage of motion extrapolation account, in our results spatial lead of moving object is also evident in flash initiated cycle. Our model, without being restricted to one special visual area, provides a generic account for FLE by emphasize on different manipulation of stationary objects and trajectory motion by the sensory system.

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33.423 **Motion reversal reveals mechanisms of perceptual suppression** Davis M. Glasser[1](davis.glasser@nyu.edu), Duje Tadin[2], Christopher C. Pack[3]; [1]Psychology, Center for Neural Science, New York University, [2]Brain and Cognitive Sciences, Center for Visual Science, Opthalmology, University of Rochester, [3]Neurology and Neurosurgery, Montreal Neurological Institute, McGill University

Human observers are extremely sensitive to motion information. Under ideal circumstances, just a few milliseconds of motion is sufficient to generate a reliable percept of direction. However, we recently reported a surprising phenomenon in which observers consistently misperceive motion direction of brief, large, high-contrast gratings (Glasser & Tadin, VSS 2013). This perceptual reversal is seen across a wide range of temporal frequencies, but disappears when either size or contrast are reduced, which suggests that this effect is a consequence of psychophysical spatial suppression (Tadin, Lappin, Gilroy, & Blake, 2003). Here, we report a simple model, an extension of work by Derrington and Goddard (1989), which captures the key characteristics of the observed motion direction reversals. Specifically, the model compares responses of model neurons tuned to opposite directions of motion. At extremely brief durations, a moving stimulus contains a comparable amount of motion energy in both directions, so both neurons are activated by a stimulus that moves in only one direction. Critically, the responses of model neurons undergo supersaturating divisive normalization (Peirce, 2007), which yields non-monotonic responses as a function of stimulus strength (contrast, size, and duration). As a result, the veridical motion signal is more strongly suppressed than the opposing signal. This simple model produces motion direction reversals and, notably, yields size, contrast, and temporal frequency tuning that match our psychophysical findings. The current model does a good job of capturing our behavioral findings, but one limitation is that it ignores the temporal dynamics of responses to brief stimuli, which may yield insights into psychophysical spatial suppression, as well as motion processing in general. In ongoing work, we are exploring the dynamics of perceptual motion reversals to elucidate possible contributions of rapid adaptation, transients, motion opponency, or other mechanisms to reversed motion percepts.

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33.424 **Vertical opponency modulates sensitivity to horizontal motion** Andrew E. Silva[1](aesilva@ucla.edu), Zili Liu[1]; [1]Department of Psychology, University of California at Los Angeles

Introduction: Motion processing involves several antagonistic interactions. For example, different directions have been found to perceptually suppress one another when simultaneously presented (directional suppression) (Snowden, 1989). Suppression also occurs when an MT neuron encounters simultaneous motions in its preferred and anti-preferred directions in the same location, resulting in a decreased neural response (opponency) (Qian & Andersen, 1994). With MT's prominence in motion processing, its neural interactions may modulate directional suppression at the perceptual level. It is therefore reasonable to hypothesize that when affected by opponent suppression, motion signals may have a reduced ability to exert directional suppression during later processing. Thus, in a presentation consisting of opponent vertical and non-opponent horizontal motion, the directional suppression acting against the horizontal motion may be reduced, resulting in greater detectability of the horizontal direction. We tested this hypothesis in the present study. Method: A motion stimulus consisted of 49 pairs of background dots and 70 randomly distributed target dots. During each trial, half of all background dots shifted up and half shifted down. In opponent trials, dots within pairs shifted in opposite directions, while in non-opponent trials, dots within pairs shifted in the same direction. All target dots shifted either left or right, and participants indicated this direction. Results: The non-opponent condition elicited a higher d′ (1.87) than the opponent condition (1.36) for horizontal motion discrimination ($n = 24$, $p < .001$). Conclusion: Opponent motion exerted stronger directional suppression than non-opponent motion, contradicting our prior hypothesis. However, a recent study suggests that some MT neurons have multiple preferred motion directions (Richert et al., 2013). Therefore, vertical opponency may suppress some horizontal-sensitive cells and result in decreased horizontal sensitivity, potentially accounting for the current results.

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33.425 **Modeling motion perception and perceptual learning in random dot kinematograms** Émilien Tlapale[1](etlapale@uci.edu), Barbara Anne Dosher[1], Zhong-Lin Lu[2]; [1]Department of Cognitive Sciences, University of California, Irvine, [2]Department of Psychology, The Ohio State University, Colombus

Random dot kinematograms (RDKs) represent a fundamental category of stimuli in the study of visual motion in both neurophysiology and psychophysics. Although models have been proposed to account for certain results from RDK experiments, none offer a quantitative account of the effects induced by systematic manipulations of the parameters of RDKs. Yet, a comprehensive consideration of those stimulus variations could provide significant constraints on models of the visual motion system. Here we propose a detailed dynamical model comprised of motion detection, motion integration and perceptual decision stages, respectively linked to cortical areas V1, MT and LIP. In addition the short term dynamics of the model are influenced by slow connectivity reweighting that leads to long term perceptual learning. We show that the model is sufficiently generic to handle a wide class of moving stimuli. It is also sufficiently precise to quantitatively reproduce the threshold curves of Watamaniuk et al (1989,1992) in which movement direction distribution of random dots, presentation duration and stimulus size are parametrically varied. The richness of those data provides constraints on the dynamics and connectivity of the model. Moreover our model provides a natural explanation for the threshold reductions associated with very broad direction distributions, which are mostly unexplained in the original study. The simple reweighting mechanism (Dosher and Lu, 1998) allows us to replicate the perceptual learning effects observed for RDKs (Ball and Sekuler, 1982,1987). Finally, we consider the impact of several noise sources at the different stages of the model, making testable predictions on their influences on threshold curves. As a whole, we present a precise yet generic model of visual motion processing which is able to quantitatively account for both the effects of parametric stimulus variations and longer term learning effects.

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33.426 **Computational modeling of paradoxical occlusion of a "near" surface** Harald Ruda[1](h.ruda@neu.edu), Guillaume Riesen[1], Ennio Mingolla[1]; [1]Computational Vision Laboratory, Northeastern University

In classic conditions surfaces that undergo accretion or deletion of texture are always perceived to be behind a comparison surface. This is the case whether surface texture elements are moving or static, and whether the boundary between surfaces is moving or static. The region that moves together with the boundary becomes the foreground, and the background undergoes accretion or deletion. However, in the recent 'Moonwalk illusion' described by Kromrey, Bart & Hegdé (PLoS ONE 6(6), 2011) this is no longer true. Here the surface that undergoes accretion and deletion appears to be in front of the comparison surface. The change from classical conditions is the use of random flickering noise for the comparison surface instead of a coherent static or moving region. [demonstration at www.neu.edu/cvl] The ForMotionOcclusion model (Barnes & Mingolla, Neural Networks 37:141-164, 2013) includes two streams for computing motion signals and boundary signals. The motion stream first computes elementary motion signals; these are smoothed with a center-surround filter, which then supports the computation of accretion and deletion signals. The static stream computes boundaries based on contrast but also includes information about the locations of motion generated boundaries. The two streams generate depth percepts such that accretion/deletion signals together with boundary signals code for the 'far' depth. Plain motion signals code 'near' depth. The default code is for a 'middle' depth. The model fits the classical data as well as the observation that moving surfaces tend to appear closer in depth. Because the model separates the computation of boundaries from the computation of accretion/deletion signals, it also explains the counter-intuitive moonwalk stimulus. The lack of a distinct boundary due to the flickering makes accretion/deletion a non-effective cue for depth ordering. We show simulations demonstrating this result.

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Motion Perception: Local motion and optic flow

Sunday, May 18, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

33.427 Counterchange, But Not Motion-Energy, Determined Motion Perception Integrates Dichoptically Presented Motion Information

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Visual motion perception is putatively a composite process enacted by different mechanisms that are sensitive to different types of information, and whose functions may be redundant depending on stimulus attributes. An important consideration in distinguishing between mechanisms is whether they can integrate information that is presented dichoptically (i.e., half of a motion sequence presented is presented to one eye, and the other inter-leaved half is independently presented to the other eye). Method. Two experiments compared the dichoptic presentation of six-step apparent motion stimuli (steps 1, 3, and 5 to one eye and 2, 4, and 6 to the other eye) to their monoptic viewing (either steps 1-3-5 or 2-4-6). In Experiment 1 the stimulus was a translating Kanizsa square (its edges were illusory contours); perceived motion was attributable to the detection of counterchanging activation (i.e., oppositely signed changes in activation at pairs of locations). In Experiment 2 the stimulus was a set of stationary literal squares whose luminance was sequentially incremented; perceived motion was attributable to the detection of motion energy. Results. The perception of motion was better for dichoptic than monoptic presentations of the translating Kanizsa squares. While motion could be perceived for faster speeds than the Kanizsa stimuli, there was little difference between dichoptic and monoptic presentations for squares whose luminance was sequentially incremented. Discussion. Information that was dichoptically presented to the two eyes was integrated for counterchange determined Kanizsa motion, but not for motion-energy determined spreading- luminance motion. The results are consistent with Lu and Sperling's (1995) characterization of 1st- and 3rd-order motion systems. Motion-energy determined spreading-luminance motion is fast and monocular (1st-order), whereas the counterchange determined motion of illusory surfaces favors slower speeds and benefits from integrating information presented separately to the two eyes. The latter supports counterchange as the mechanism underlying 3rd-order motion perception.

33.428 Speed tuning of human Ocular Following Responses (OFRs) depends on orientation bandwidth in noise stimuli.

Boris Sheliga[1](bms@lsr.nei.nih.gov), Christian Quaia[1], Edmond FitzGibbon[1], Bruce Cumming[1]; [1]Laboratory of Sensorimotor Research, National Eye Institute, National Institutes of Health

We measured the speed tuning of horizontal OFRs to drifting 1D noise (vertical barcode) and 2D noise (random checkerboard) stimuli. For both stimuli the relationship between speed and response magnitude was well fit by a Gaussian curve, but the peak response occurred at lower speeds (by a factor of 1.28) for 2D noise. We then measured responses to intermediate stimuli, constructed from abutting strips of 1D noise. When the strip height equals the noise line width, the stimulus is 2D noise. As the strip height increases, the orientation bandwidth decreases, approximating 1D noise. We varied strip height from ~0.4° (64 strips, 2D noise) to ~25° (1 strip, 1D noise), keeping the total height (and width) of the stimulus constant, and measured the speed tuning curve. The speed associated with the strongest response increased systematically with strip height. Using sinusoidal stimuli drifting at a constant temporal frequency, we previously showed (Sheliga et al. 2013) that, for any one spatial frequency, responses vary with strip height, and that the optimum strip height is proportional to stimulus wavelength. This nonlinear summation can explain the results presented here: as strip height increases, lower spatial frequency channels play a stronger role, thus leading to higher preferred speeds. This explanation assumes that optimal temporal frequencies are independent of spatial frequency and contrast, which we also show to be true for OFRs. The explanation also predicts larger changes in preferred speed when pink noise rather than white noise is used, and we confirm this empirically (1.40 vs. 1.26). Thus nonlinear spatial summation within frequency channels can explain the difference in preferred speeds for 1D vs. 2D noise.

Acknowledgement: NEI Intramural Program

33.429 No motion-induced sensitivity modulation for chromatic gratings.

Rumi Hisakata[1,2](hisakata@fechner.c.u-tokyo.ac.jp), Shin'ya Nishida[1], Alan Johnston[3]; [1]NTT Communication Science Laboratories, NTT, [2]Japan Society for the Promotion of Science, [3]Cognitive, Perceptual and Brain Sciences, University College London

De Valois and De Valois (1991) showed a moving carrier within a static envelope induced a shift in the apparent position of the Gabor patch. It is known that many kinds of motion induce position shifts, however, the underlying mechanism remains unclear. Recently Roach, McGraw and Johnston (2012) showed that motion modulates the sensitivity to an abutting target depending on the relative phase between the target and inducer grating. Phase dependency was found at the leading position but not at the trailing position. However, the relationship between the position shifts and the sensitivity modulation effect remains a subject of debate. We explored this relationship by examining whether a chromatic grating, which can give rise to position shifts, also induces asymmetric phase dependent sensitivity modulation. There were two conditions, equiluminance and luminance. We used a red-green grating in the equiluminance condition and a yellow-black grating in the luminance condition. Equiluminance was measured by the minimum motion technique (Anstis & Cavanagh, 1983). The inducer size was 1 deg x 7 deg and the target size was 1 deg x 1 deg. For both the spatial frequency was 1cpd and the temporal frequency was 5Hz. The relative phase between the inducer and target was manipulated. We used 2AFC staircase to measure the contrast thresholds. We did not find asymmetric phase dependent sensitivity modulation in the equiluminance condition but the contrast thresholds with the motion inducer were higher than that in the no inducer condition, indicating a motion masking effect. We conclude that this modulation effect does not explain the position shifts due to chromatic motion and that sensitivity modulation does not affect position estimation in our visual system.

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33.430 A new swaying bar illusion

Sae Kaneko[1,2](sakaneko@ucsd.edu), Rumi Hisakata[3,2]; [1]Dept. of Psychology, University of California, San Diego, [2]Japan Society for the Promotion of Science (JSPS), [3]NTT Communication Science Laboratories, NTT

We report a novel illusion of motion. A stationary colored bar lay on an achromatic background whose luminance was modulated from below to above the bar luminance and back again. The stationary bar appeared to "sway" back and forth in sync with the background modulation. The illusory motion was strongest in the near periphery but could also be observed in the fovea. We explored this illusion using rating and matching methods. Observers viewed a cyan bar (4° long x 0.33° wide) on a luminance modulating background (1 Hz) for a time period of 4 s, and rated the motion impression on a

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7 point scale (0: no motion, 6: very strong motion). Stimulus was presented in four different locations (right/left/upper/lower field, all 4 deg eccentricity). Observers also reported the direction of the motion by adjusting the angle of a matching line. Bar luminance was varied on different trials from lower to higher than the background luminance range. Bar orientation was 0 (vertical), 45 or 90 (horizontal) deg. Results: 1. the illusory motion was perceived only when the bar luminance was within the background modulation range; 2. the perceived direction of motion was orthogonal to the target bar. For example, a vertical bar always oscillated horizontally. We have two hypotheses: the first is that when the bar changes its polarity, it is sensed by different channels that are not in exact spatial register, and the second is the momentary uncertainty of the bar's position at the moment when it is equiluminant with the background. We will discuss these possibilities.

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33.431 The effects of local object motion and binocular disparity on collision detection

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Previous research has demonstrated the advantage of binocular information for motion in depth. The current study examined the roles of binocular disparity on the detection of an impending collision when distant objects in the background had projected velocities due to observer motion. We presented observers with 3D scenes consisting of either a ground plane or a ground plane with objects in the scene that extended vertically from the ground plane. In addition, observers were shown an approaching sphere that was positioned above the ground texture. The displays simulated forward observer motion resulting in velocities adjacent to the approaching object when scene objects were present. For half of the trials the sphere was on a collision path with the observer whereas the remaining trials the sphere would pass by the observer. Before the full collision trajectory (7200ms) was shown the trial terminated and observers indicated whether or not the sphere was on a collision path. Three independent variables were manipulated: viewing condition (binocular vs. monocular), the presence of adjacent velocities (scene objects present vs. scene objects absent), and display duration (1000ms vs. 5000ms). We found that sensitivity to detect a collision (d') decreased with display duration ($F(1, 6)= 28.634$, $p= 0.002$) and with the presence of scene objects ($F(1, 6)= 43.475$, $p<0.001$). There was a non-significant trend of viewing condition with improved performance observed in the binocular disparity conditions at longer display durations. However, similar performance declines occurred for both monocular and binocular viewing conditions when object motion adjacent to the approaching collision object was present. These results suggest that the addition of binocular disparity does not allow for observers to overcome the effect of local motion from objects in the scene, but it does provide a slight benefit when viewed for a longer temporal period.

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33.432 Primacy of speed in the processing of motion during smooth pursuit

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An important goal for models of motion processing is to recover object speed, yet few psychophysical studies have investigated the importance of speed to the visual system. Using static fixation, Reisbeck & Gegenfurther (1999, Vision Research, 39, 3267-3285) showed speed dominated the discrimination of moving gratings, as opposed to spatial and temporal cues. But observers typically pursue moving objects, so I investigated whether speed remained dominant for pursued targets by measuring discrimination contours in the distance-duration plane. If speed dominates, stimuli moving over different distances and durations should be more difficult to discriminate when they have the same speed. Resulting discrimination contours (ellipses) should therefore be oriented obliquely along iso-speed lines, as opposed to parallel to the distance-duration axes. Because extra-retinal signals and retinal-flow signals both help to estimate the speed of pursued stimuli, contours were measured with and without visible static backgrounds. Trials consisted of a horizontally-moving dot shown without background (no flow) or with horizontal lines (reduced flow) or vertical lines (high flow). Two standard stimuli (4deg/s, 1s or 2s, 4 or 8deg) and one test were shown in random sequence, with the speed, distance and duration of the test determined by a fixed orientation in the distance-duration plane. Sixteen orientations were investigated, and discrimination thresholds determined using a staircase procedure. For 3 observers, discrimination ellipses were oriented obliquely along iso-speed lines, suggesting that speed was the dominant cue in all conditions. Furthermore, ellipses became less elongated as the salience of flow increased. This suggests that visible backgrounds enhance distance cues not speed cues, because adding flow should have enhanced the latter and so elongated the ellipses (note duration cues were identical across conditions). Nevertheless, speed dominated performance throughout, underscoring the primacy of this cue for the processing of motion with or without pursuit.

33.433 Temporal and Speed Tuning in Brain Responses to Local and Global Motion Patterns

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Both the detection of local motion speed and direction and the integration of these components into global patterns take time (Burr & Santoro, 2001). Here we investigated the extent to which visual evoked potentials to coherence-modulating radial motion patterns varied as a function of dot lifetime. The goal was to determine the pattern of temporal tuning for local and global motion responses. Radial (expansion/contraction) optic flow patterns elicit robust evoked potential responses in adults (Gilmore et al., 2007). VEP responses also indicate pattern-specific tuning at slow speeds, with lateral occipital areas displaying high activation to radial patterns at slow speeds (Fesi , Thomas, Gilmore, under review). Speed tuning at the dot update rate (F2) and intermodulation harmonics indicated an interaction between global motion coherence and local motion responses. We recorded steady-state visual evoked potential (SSVEP) responses from (n=12) adults with a 128 electrode net. Participants viewed displays depicting a radial expansion/contraction pattern with dots moving at a constant 2 deg/s. Random dot displays (7 amin dots, 79.4 cd/m2, density = 10%) modulated in time from 0% (incoherent) to 100% coherent global motion at .6 Hz, 1.2 Hz, and 2.4Hz (F1). Dot lifetime varied between 83, 167, 333, and 4,160 ms at the dot update rate of 24 Hz (F2). Phase-locked EEG amplitudes at low order integer harmonics (1F1 and 2F1), the dot update rate (1F2: 24 Hz), and intermodulation harmonics (1F2+/-1F1) were analyzed. The highest and lowest modulation frequencies elicited similar activation across channels except at the dot lifetime of 167 ms where strong lateral occipital activation was observed. For all conditions, we replicated the midline occipital activation shown in a previous study at the dot update rate (F2) and the intermodulation harmonics. Results indicate that spatial tuning and the timing of local motion integration varies by coherence modulation frequency.

33.434 A direct influence of stimulus orientation on perceived motion trajectory

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Increasing psychophysical evidence shows mutual interactions between motion and pattern information in visual processing. It is well known that motion signals directly affect the perceived position of a visual stimulus; motion-induced position shift (DeValois & DeValois, 1991). The other studies also report the influence of pattern on motion as the inhibitory effect of background orientation on motion perception, and as the perception of global motion structure from Glass patterns (Geisler, 1999; Ross et all. 2000). Here, we further demonstrate a direct influence of stimulus orientation on the perceived motion trajectory; orientation-induced motion shift (OIMS). In our typical display, a horizontally oriented Gabor pattern (1.6 c/deg) changed its position horizontally with a frame duration of 50 msec and ISI of 25 msec. The observers viewed the stimulus presented at 5.1 deg below the fixation point, and indicated whether the target motion was biased upward or downward. The amount of the apparent bias was measured, by means of a cancelation technique, for various orientations of the stimulus. The results showed that the perceived direction was systematically biased towards the stimulus orientation. The bias was the largest (~+-5 deg) at orientations of +-15 deg, and was more profound as the number of frames was small. When the display consisted of large number of frames, the perceived bias was small when the observer focused on the last few frames as compared to when they focused on the first few frames. This was as if orientation signals and its perpendicular motion signals compete for the conscious motion percept. By using the tilt aftereffect, we also found that the direction shift was consistent with the perceived, but not physical, orientation of the stimulus following adaptation. These results suggest that cortical orientation signals directly affect the perception of motion trajectory.

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33.435 The accuracy of object motion perception during locomotion

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To avoid and intercept moving objects, moving observers must perceive object motion in world coordinates (Fajen, Parade, & Matthis, 2013). This is complicated by the fact that the local optical motion of moving objects is influenced by both observer and object motion, and reflects object motion in observer coordinates. It has been proposed that observers recover object

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motion in world coordinates by using global optic flow to factor out the influence of self-motion. However, judgments of object motion during simulated self-motion are biased, as if the visual system does not completely compensate for the influence of self-motion. Perceived object motion is less biased when both visual and vestibular self-motion information is available, but is still not completely veridical. The aim of this study was to investigate the accuracy of object motion perception when self-motion is real and actively generated by walking over a ground surface. The experiment was conducted in a virtual environment viewed through a stereoscopic head-mounted display. Subjects observed an object move along a textured ground surface across their path and judged whether the object was approaching or retreating. They performed this task while remaining stationary and viewing optic flow simulating self-motion and while actually walking. We found a bias to perceive objects as approaching when self-motion was simulated. However, judgments were unbiased when self-motion was real, demonstrating that observers are capable of accurately perceiving object motion in world coordinates when self-motion is actively generated by walking over a ground surface. We introduce a new model to account for these and previous findings. The model proposes that non-visual information generated during locomotion is used not to improve the self-motion estimate but rather to allow object motion to be perceived relative to the physical ground surface, so that locomotion and object motion perception are in the same reference frame.

Acknowledgement: R01EY019317

33.436 **Human self-motion sensitivity to visual yaw rotations** Alessandro Nesti[1](alessandro.nesti@tuebingen.mpg.de), Karl Beykirch[1,2], Paolo Pretto[1], Heinrich Bülthoff[1,3]; [1]Department of Human Perception, Cognition and Action, Max Planck Institute for Biological Cybernetics, Tübingen, Germany, [2]AMST-Systemtechnik GmbH, Ranshofen, Austria, [3]Department of Brain and Cognitive Engineering, Korea University, Seoul, Korea

Whilst moving through the environment humans use vision to discriminate different self-motion intensities and to control their action, e.g. maintaining balance or controlling a vehicle. Yet, the way different intensities of the visual sensory stimulus affect motion sensitivity is still an open question. In this study we investigate human sensitivity to visually induced circular self-motion perception (vection) around the vertical (yaw) axis. The experiment is conducted on a motion platform equipped with a projection screen (70 x 90 degrees FoV). Stimuli consist of a realistic virtual environment (360 degrees panoramic color picture of a forest) rotating at constant velocity around participants' head. Visual rotations are terminated by participants only after vection arises. Vection is facilitated by the use of mechanical vibrations of the participant's seat. In a two-interval forced choice task, participants discriminate a reference velocity from a comparison velocity (adjusted in amplitude after every presentation) by indicating which rotation felt stronger. Motion sensitivity is measured as the smallest perceivable change in stimulus velocity (differential threshold) for 8 participants at 5 rotation velocities (5, 15, 30, 45 and 60 deg/s). Differential thresholds for circular vection increase with stimulus intensity, following a trend best described by a power law with an exponent of 0.64. The time necessary for vection to arise is significantly longer for the first stimulus presentation (average 11.6 s) than for the second (9.1 s), and does not depend on stimulus velocity. Results suggest that lower sensitivity (i.e. higher differential thresholds) for increasing velocities reflects prior expectations of small rotations, more common than large rotations during everyday experience. A probabilistic model is proposed that combines sensory information with prior knowledge of the expected motion in a statistically optimal fashion. Results also suggest that vection rise is facilitated by a recent exposure.

33.437 **Adaptation to a non-uniform motion pattern reveals a mechanism to encode local flow changes.** Kazushi Maruya[1](kazushi.maruya@gmail.com), Shin'ya Nishida[1]; [1]NTT Communication Science Laboratories

At an early stage, visual motion is processed by a bank of local detectors, each tuned to a narrow range of motion direction. To investigate how the brain encodes the spatiotemporal relationship of the detector bank outputs, past studies have mainly focused on relatively simple optical flows, i.e., translation, rotation and expansion/contraction. However, we can effortlessly perceive many natural scenes containing complex non-uniform motion patterns produced by multiple rigid objects or non-rigid substances. In an attempt to understand the mechanism underlying these percepts, we examined whether and how the visual system adapts to non-uniform motion flows. Our stimulus was an array of Gabor plaids, each moving in some direction within a stationary Gaussian window. In the non-uniform adaptation stimuli, two local motion directions spatially alternated every two rows and columns in a checkerboard fashion, with the spatial phase of the checkerboard boundaries being randomly updated every 1s. In the uniform adaptation stimuli, one local direction was presented at a time, and switched to the other direction every 1s. The test pattern was a non-uniform checkerboard pattern defined by a motion direction change, and the minimum direction difference with which observers could detect the checkerboard structure was measured by the method of adjustment. We found a significant increase in the threshold direction difference after adaptation to non-uniform motion stimuli in comparison to adaptation to uniform motion stimuli, although the state of local motion adaptation was expected to be similar between the two conditions. That is, a judgment of non-uniformity became difficult after prolonged viewing of a non-uniform motion pattern. Furthermore, the aftereffect was observed even when the local motion directions for the adaptation and test stimuli were widely separated. These results suggest the existence of specialized mechanism encoding non-uniform local motion flow changes.

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33.438 **Angular, speed and density tuning of flow parsing** Diederick C Niehorster[1](dcnieho@gmail.com), Li Li[1]; [1]Department of Psychology, The University of Hong Kong, Pokfulam, Hong Kong SAR, China

Recent studies have suggested that the visual system subtracts the optic flow experienced during self-motion from the retinal motion of the environment to recover scene-relative object motion, a phenomenon called "flow parsing". The psychophysical characteristics of this process however remain unclear. Here, by measuring the gain with which flow parsing is performed, we examined how flow parsing is affected by the angle between the object motion and the background flow at the object's location (Experiment 1), the self- or the object motion speed (Experiments 2 and 3), and the density of the elements in the background flow (Experiment 3). In each 0.5-s trial, the display (83°H x 83°V, 60 Hz) simulated forward self-motion at .5–5 m/s toward a frontal plane covered with 10–5000 white random dots placed at 2 m. A red probe dot moved leftward or rightward at 1–10 deg/s on the frontal plane. A component toward the FOE was added to the probe's horizontal retinal motion under the control of an adaptive staircase to determine when the probe was perceived to move horizontally. The results show that flow parsing was strongly affected by each of the factors we varied. Specifically, flow parsing gain decreased exponentially as the object motion direction deviates from the background flow at its retinal location. Surprisingly, flow parsing gain also decreased exponentially with the increase of the simulated self-motion speed. Flow parsing gain increased linearly with the object motion speed and increased logarithmically with the density of the background flow. We conclude that while increasing the object motion speed and the number of elements in the scene helps the perception of scene-relative object motion during self-motion, the performance is best at normal walking speed and when the object moves in the same direction as the background flow at its retinal location.

Acknowledgement: Hong Kong Research Grant Council, HKU 7480/10H and PF09-3850

33.439 **When does a moving object influence the perception of heading?** Oliver W. Layton[1,2](owl@bu.edu), Brett R. Fajen[1]; [1]Cognitive Science, Rensselaer Polytechnic Institute, [2]Center for Computational Neuroscience and Neural Technology, Boston University

Unlike in a rigid environment, the presence of an independently moving object may bias human heading judgments during self-motion. Existing research suggests that an object moving laterally with respect to the observer's translation biases heading only when it crosses the observer's focus of expansion (FoE) (Warren & Saunders, 1995; Royden & Hildreth, 1996), which specifies the direction of travel in the absence of rotation (Gibson, 1950). Bias has only been demonstrated in dot-defined environments that lack depth variation (e.g. frontal wall). We sought to characterize the range of conditions in which moving objects impact heading perception. We investigated how proximity to the FoE and approach trajectory relative to heading of a moving object impacted heading perception in environments consisting of a dot- or texture-defined fronto-parallel plane, a ground plane, or both. Twelve subjects viewed simulated self-motion (±3°, ±9°, ±15°) on a rear projection screen (100°x80°) and indicated their perceived heading by adjusting the position of a post-motion probe. The object (initially 11°x11°) was positioned to occlude the FoE for much (Near condition) or none (Far condition) of the trial. Consistent with Warren & Saunders, we found bias in the direction opposite of the object motion when the object moved toward and crossed the path (~3°; Near condition). Unexpectedly, bias was observed when the object moved close to, but did not cross, the observer's path (~3.5°; Far condition). Objects initially positioned close to or far from the path that moved away did not yield bias. Our results show that moving objects bias heading even in environments with depth variation and even

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when the moving object approaches but does not occlude the FoE. The bias is consistent with models that propose a broad spatial pooling of units tuned to motion in area MT of primate visual cortex (Layton et al. 2012).

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33.440 **Optimal integration of retinal and extra-retinal signals for heading perception** Shenbing Kuang[1](kuangsb@psych.ac.cn), Jinfu Shi[1,2], Yang Wang[1,2], Tao Zhang[1]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Psychology, Chinese Academy of Sciences, [2]University of Chinese Academy of Sciences

As we move forward in the environment we experience a radial expansion of retinal images, of which the center corresponds to the instantaneous direction of self-motion (heading). Humans and non-human primates can precisely perceive their heading directions even when they are making simultaneous pursuit eye movements, which shifted the center of the expansion pattern on retina. Previous controversial studies have shown that both retinal and extra-retinal strategy can account for accurate heading perception during pursuit. Here we propose that the visual system flexibly combine the retinal and the extra-retinal signals in a Bayesian-like statistically optimal fashion. To test predictions derived from this Bayesian-like framework, we devised a pair of experiments in which we independently manipulated the reliability of each input signals in a two alternative heading direction discrimination task. Two aspects of visual signal reliability were tested separately, the simulated heading speed and element motion coherency. Our results showed that the contribution of extra-retinal signals to heading judgments increased with increasing pursuit eye movement speed, and decreased with increasing simulated heading speed. Similarly, observers were relying on more of retinal signals instead of extra-retinal signals to support their heading judgments when we increased the coherency of element motion in retinal flow. We hope our findings can be helpful to unify previous differing observations in a rather sample framework.

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Eye movements: Pursuit

Sunday, May 18, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

33.441 **Contrast-dependent motion processing : insight from ocular tracking dynamics** Anna Montagnini[1](anna.montagnini@univ-amu.fr), Guillaume Masson[1], Laurent Madelain[1,2]; [1]Institut de Neurosciences de la Timone, CNRS & Aix-Marseille University, France, [2]Psychology Department, Ureca – Universite Lille 3, Villeneuve D'Ascq, France

The underestimation of speed for low-contrast, slowly moving objects is a well established phenomenon. Coherently, smooth tracking of low-contrast stimuli is impared both during pursuit initiation (longer latency, Spering et al., 2005) and steady state (lower gain). We have recently probed the dynamic perturbations of steady state pursuit gain during periodic modulations of target-background contrast (using a variant of the Footstep illusion stimulus, Madelain et al, 2013), providing further support for a close relation between motion perception and tracking eye movements across various visual conditions. Importantly, smooth pursuit data allows one to reliably track fine details of the dynamic modulations of visual processing across time. We used a Kanitzsa illusory rectangle as a pursuit target (6°×8°), with the four gray inducers presented at high (100 cd/m2) or low luminance (1 cd/m2) on a yellow bright background (100cd/m2). Subjects tracked the center of the illusory target during a motion ramp at 8°/s. At an unpredictable time (starting with equal probability at 70, 140, 210, 280ms or never wrt target motion onset) the inducers changed luminance (from high to low contrast in the first condition and from low to high contrast in the second condition) for 500ms and then reverse back. We found that the effect of luminance-contrast on steady-state pursuit gain was stronger during the luminance change transitions than with constant luminance. In addition, a very similar dynamic oculomotor pattern was observed for the different onset times of the transient luminance change, arguing against a functional difference of contrast-dependent speed processing for illusory objects between pursuit initiation and the closed-loop phase. Overall these results suggest that contrast-dependent perturbations of velocity estimate depend on the integration of dynamic motion cues in a more complex way than previously thought, possibly taking into account the short term history of visual motion.

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33.442 **Beyond simply faster and slower: exploring paradoxes in speed perception** Andrew Isaac Meso[1](andrew.meso@univ-amu.fr), Claudio Simoncini[1], Laurent Perrinet[1], Guillaume S. Masson[1]; [1]Institut de Neuroscience de la Timone, CNRS & Aix-Marseille Université

Estimating object speed in visual scenes is a critical part of perception. While various aspects of speed computation including discrimination thresholds, neural mechanisms and spatial integration mechanisms have been studied, there remain areas to elucidate. One is the integration of information across spatio-temporal frequency channels to compute speed. We probe this integration with a 2-AFC psychophysical task in which moving random phase noise stimuli are used with experimenter defined frequency parameters and bandwidths to target specific neural populations. They are presented for 300ms in a large square aperture with smooth eye movements recorded while speed discrimination judgements are made over two intervals. There is no instruction to observers to pursue the stimuli and no pre trial saccade to induce a classic ocular following response. After a latency, eye movements follow the stimulated direction presumably to facilitate the speed judgement. Within each of the two intervals, we randomly vary a range of spatial frequency and speed parameters respectively such that stimuli at the centre of the ranges are identical. The aim is to characterise the speed response of the eye movements recorded in a context which creates an ocular motor 'action' during a perceptual task instead of artificially separating the two. Within the speed varied intervals, averaged eye movements are systematically modulated in strength by stimulus speed. Within the spatial frequency intervals, higher frequencies perceived as faster in discrimination responses interestingly show no corresponding strengthening of eye responses particularly at higher contrasts where they may be weaker. Thus for a pair of stimuli matched for contrast and perceived speed, this early eye response appears to be driven by a contrast dependent low level motion energy like computation. We characterise an underlying spatial frequency response which is shifted towards lower frequencies, unlike the perceptual responses and is probably separate from perception.

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33.443 **Unsupervised dynamic morphing of a spatiotemporal visual event during its oculomotor tracking** Clara Bourrelly[1,2](clara.bourrelly.int@gmail.com), Julie Quinet[2], Laurent Goffart[2]; [1]Laboratoire Psychologie de la Perception, Université Paris-Descartes, Paris, France, [2]Institut de Neurosciences de la Timone, Aix-Marseille Université, Marseille, France

A target moving in the visual field triggers an interceptive saccade that brings the target image onto the fovea. This foveation is maintained more or less efficiently by two types of tracking eye movements: low-velocity movements (pursuit) and catch-up saccades. Fleuriet & Goffart (2012) hypothesized that the oculomotor system is driven by an estimate of the expected current target location. We suggest that this ability to continuously encode, in spite of neural delays, the "here-and-now" position of a moving target, requires memorization of the trajectory. We further developed this hypothesis by studying how three inexperienced monkeys tracked a small moving target. Their eye movements were recorded with the search coil technique. Each trial started with foveation of a central target which, after a variable interval, stepped 16 deg upward/downward along the vertical meridian, then immediately moved horizontally and smoothly for 16 deg with a constant, accelerating or decelerating velocity, and disappeared. The monkey was rewarded if its gaze tracked the target within a relaxed fixation window (8 deg radius). We analyzed the evolution of eye movements over several consecutive days. Initially, the tracking was mostly composed of saccades separated by periods during which gaze slowly moved toward the target. Exception made of saccades, the gaze lagged behind the target. The pursuit gain increased with the number of trials and training days. The increase in pursuit velocity was associated with a reduction in the number and amplitude of catch-up saccades and gaze sometimes moved as if it were locked onto the target. Our work shows that the ability to continuously maintain the image of a moving target onto the fovea evolves over time. With practice, foveal signals dominate the visuomotor channels and the tracking transitions to a mode that mimics the target dynamics.

Acknowledgement: ERC Advanced Grant # 324070 (POSITION) to Patrick Cavanagh and ANR (VISAFIX) to Laurent Goffart

33.444 **Smooth pursuit of flicker-defined motion** Jeffrey B. Mulligan[1](jeffrey.b.mulligan@nasa.gov), Scott B. Stevenson[2]; [1]NASA Ames Research Center, [2]University of Houston College of Optometry

We examined the pursuit response to stimuli defined by space-variant flicker of a dense random dot carrier pattern. On each frame, every element of the pattern could change polarity, with a probability given by a two-dimensional Gaussian distribution. A normal distribution produces a circular region of twinkle, while inverting the distribution results in a spot of static texture in a twinkling surround. In this latter case, the carrier texture could be stationary, or could move with the twinkle modulator, thereby producing first-order motion in the region of the spot. While the twinkle-defined spot produces a strong sensation of motion, the complementary stimulus defined by the absence of twinkle does not; when viewed peripherally, it appears to move in steps even when the generating distribution moves smoothly. We examined pursuit responses to these stimuli using two techniques: 1) the eye movement correlogram, obtained by cross-correlating eye velocity with the velocity of a randomly-moving stimulus; and 2) delayed visual feedback, where transient stabilization of a target can produce spontaneous oscillations of the eye, with a period empirically observed to vary linearly with the applied delay. Both techniques provide an estimate of the internal processing time, which can be as short as 100 milliseconds for a first-order target. Assessed by the correlogram method, the response to flicker-defined motion is delayed by more than 100 milliseconds, and significantly weaker (especially in the vertical dimension). When initially presented in the delayed feedback condition, purely saccadic oscillation is observed. One subject eventually developed smooth oscillations (albeit with significant saccadic intrusions), showing a period-versus-delay slope similar to that observed for first-order targets. This result is somewhat surprising, given that we interpret the slope of the period-versus-delay function as reflecting the balance between position- and velocity-sensitive inputs to pursuit.

33.445 Small foveal stimuli render smooth pursuit less smooth

Stephen Heinen[1](heinen@ski.org), Elena Potapchuk[1], Scott Watamaniuk[2]; [1]Smith-Kettlewell Eye Research Institute, [2]Department of Psychology, College of Science and Mathematics, Wright State University

Smooth pursuit eye movements follow moving objects to prevent retinal image blurring. While modeled as motion-driven, the pursuit system is studied with a weak and unnatural motion stimulus, a small, foveal spot more ideal for inducing saccades, which shift gaze between stationary objects. We showed previously that large, random dot stimuli (10 deg) invoke fewer saccades than the spot, and increase open-loop gain (Heinen & Watamaniuk, 1998). This could occur if motion summation created a stronger pursuit signal, or, alternatively, if peripheral stimulation reduced the need to reposition the fovea. To test between these alternatives, observers pursued a single dot, or configurations of 4 and 5 dots, designed to differentially probe foveal and peripheral contributions to pursuit. The 5-dot stimulus was arranged in a 6 deg "+" configuration. The 4-dot stimulus was arranged identically, but with no central spot. Consistent with our previous results, 4 dots yielded fewer saccades and higher open-loop gain than the single spot. However, while the 5-dot stimulus further increased open-loop gain, it induced almost as many saccades as the spot, contradicting the summation hypothesis, and suggesting that the salient foveal spot was triggering saccades. In a second experiment using only 4-dot configurations with different diameters (1-12 deg), more saccades were present when the configuration was small and stimulated the fovea, but open-loop gain remained constant with configuration size. The results provide evidence that two independent mechanisms subserve pursuit, one that corrects position error between the fovea and a salient feature, and another that is driven by motion. We characterize the sensitivity of position and motion mechanisms to the different dot configurations using motion/position "Punnett squares", analogous to the characterization of the expression of phenotypes in genetics.

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33.446 Foveating a moving target, here-and-now

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It is commonly believed that the visual motion signals are used to predict the future position of a moving target. Yet, the signals that drive the oculomotor system actually correspond to an estimate of target position expected here-and-now rather than an estimate of any undefined future position (Fleuriet & Goffart 2012). Therefore, we searched for the extrapolation limits and found that this estimate requires learning. First, we studied saccades toward a target moving horizontally in the upper/lower visual field for durations that gradually increased from 50 to 800 ms. The short motion triggered saccades but no pursuit. Control saccades toward static targets were also recorded as a baseline to reveal an extrapolation that was rather limited. After the progressive training, saccades were followed by smooth tracking at the longest duration (Bourrelly et al. VSS 2014). Following this training, short duration stimuli still triggered saccades without pursuit. We next studied "occlusion" training starting with the 800 ms motion, but then introducing a short occlusion in the middle of the trajectory. Over consecutive days of training, the occlusion was increased in duration from 100 to 300 ms. Gradually, pursuit-like tracking appeared during the occlusion, even though the initial segment of visible motion was still only 100 to 200 ms, a duration which did not trigger pursuit in the first experiment. We then tested the initial motion segments with no subsequent reappearance and found that now the saccades were followed by a slow pursuit-like eye movement, as if the monkeys were tracking an invisible target. Our work shows the limits of extrapolation within the visuo-oculomotor system. The signals that encode the spatiotemporal trajectory and drive the on-going tracking behavior mostly result from interpolation mechanisms. Our research should allow identifying the neural channels by which the mnemonic signals dynamically guide the on-going tracking response.

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33.447 Anticipatory smooth eye movements elicited by symbolic cues

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Anticipatory smooth pursuit eye movements can be elicited by cues that signal the future direction of target motion (e.g., Santos et. al., 2012). A comparison of the effectiveness of cues, and their sensitivity to temporal parameters such as duration or delay, could shed light on mechanisms responsible for initiating anticipatory pursuit. Subjects pursued a disc that moved (170'/s) inside an inverted Y-shaped tube. The disc could travel down either right or left oblique branch of the tube (p=.5). Three cues were tested: (1) Natural: barrier that blocked the untraveled branch; (2) Arbitrary/local: bar at the top of the tube indicated the branch by being on the same side. (3) Arbitrary/global: color of the tube (red or green) indicated the branch. Cue type affected anticipatory pursuit. Horizontal eye velocity at the time the disc entered the oblique branch was approximately twice as fast for the natural barrier cue than either arbitrary cue. Timing of cue presentation also affected anticipatory pursuit. Delaying the presentation of the cue until the disc approached the choice point had a similar effect on all cues. Anticipatory eye velocities decreased when the cue was available <200ms before it entered the branch. Removing the cues after the onset of target motion (so that only memory of the cue was available) had different effects depending on cue type. While removal of arbitrary cues had no effect, anticipatory pursuit was reduced substantially when the barrier cue was removed >100ms before the disc entered the branch. Anticipatory eye movements were reduced to levels found for the arbitrary cues. These results suggest that there are different mechanisms generating anticipatory smooth eye movements. One mechanism may depend on arbitrary associations that can be learned. Another mechanism evoked by naturalistic cues, such as the barrier, may be responsible for producing higher anticipatory eye velocities.

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33.448 Attention allocation during pursuit is broad and symmetric, but can be limited by set size and crowding

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Attention during pursuit is often found to be asymmetrically allocated, with more attention ahead of the pursuit target than behind it (e.g., van Donkelaar & Drew, 2002; Kahn et al., 2010). However, these studies used transiently appearing targets that attract attention. Lovejoy et al. (2009) controlled for luminance transients, and found the attention span to be tightly (±1 deg) and symmetrically distributed around the pursuit target. However, their stimulus, a linear array of 15 characters (0.6° spacing) may have artificially constrained attention due to crowding. We tested this hypothesis with the same character identification task but arranged the characters in a cross configuration and varied element spacing (0.6°, 2.0°, 4.0°) and set size (5, 9). All elements started as digital '8's, and after a random fixation period began moving as a unit. Shortly after movement onset, all elements changed briefly to either a '2' or '5' except for one probe element that changed to either an 'E' or a '3'. All elements then returned to '8's for the remainder of the trial, and the task was to identify the probe element. Eye movements were measured under all conditions (EyeLink 1000 @ 1000 Hz). We first replicated the Lovejoy et al. experiment, and found attention tightly centered on the pursuit target. However, stimuli with fewer elements and larger inter-element spacing produced wider scopes of attention, extending more than ±4.0° horizontally and vertically. We also found the same span of attention for stationary stimuli suggesting that attention does not operate differently during pursuit and fixation. We conclude that attention is flexibly allocated during pursuit, and limited by crowding and set size.

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33.449 **Women with premenstrual syndrome (PMS) symptoms, compared to non-symptomatic controls both on or off monophasic oral contraceptives, show asymmetric horizontal smooth pursuit amplitudes during their late luteal menstrual phase** Michael Wesner[1](michael.wesner@lakeheadu.ca), Emily Currie[1], Meghan Richards[1], Kirsten Oinonen[1]; [1]Psychology, Lakehead University

Despite the existence of female sex-steroid receptors throughout the CNS, little is known about the non-reproductive effects of cycling sex steroids. Given the convergent evidence for depressive and reproductive cyclic influences on behaviors related to oculomotor physiology (e.g., Braff et al., 2001; Wichniak, et al., 2000) we measured automatic smooth pursuit eye movements (SPEM) in women (pro)retrospectively screened with PMS symptoms (N=23), as non-symptomatic controls (N=23) or as controls using monophasic contraceptives (N=16). SPEM measurements were taken during the participants' late-follicular (LF) and late-luteal (LL) menstrual phase (estradiol & progesterone levels were assessed by salivary immunoenzymometric assay). Horizontal, sinusoidal tracking was done with a 60-Hz infrared eye tracker coupled to a 200-Hz CRT. A 2°-dia "yellow" dot (89 cd/m2) was superimposed on a 23-cd/m2 gray background. Target excursion was ±13.3° from fixation with peak velocity at center. Five target frequencies (0.25 to 2.0 Hz) were presented in ascending order. Eye position and gain (ocular : target peak velocity) were averaged across five cycles. Outside of main frequency effects, we noted an interaction of menstrual cycle phase and group based on five sampled sine wave positions (0° - 360°). A series of independent samples t-tests revealed a significant increase in left-to-right amplitude with lower gain for PMS women tracking the 0.25 and 0.50 Hz target. There were no significant positional errors or saccadic intrusions, nor open-loop volitional initiation differences. Only low-frequency, automatic foveated maintenance SPEM appeared to be affected by a unique, stable estradiol-level PMS cycle. This finding points away from retinotopic or craniotopic dysregulation and focuses more on brainstem operations. Whether or not estradiol specifically modulates diffuse brainstem oculomotor circuits remains unclear; but at least with regards to PMS, it appears that behavioral tracking differences can be manifested through changes (or lack of changes) in steroid levels across the menstrual cycle.

Acknowledgement: Canada Foundation for Innovation

Attention: Reward and arousal

Sunday, May 18, 8:30 am - 12:30 pm
Poster Session, Pavilion

33.501 **The color of money: Value-driven selectivity enhancements** Árni Gunnar Ásgeirsson[1](arnigunnarasgeirsson@gmail.com), Árni Kristjánsson[2], Kristín Vala Einarsdóttir[2], Claus Bundesen[1]; [1]Center for Visual Cognition, Department of Psychology, University of Copenhagen, [2]Department of Psychology, University of Iceland

Current behavior is largely determined by behavioral history and it's consequences. How environmental rewards can shape the frequency and quality of behavior, has, however, only recently come under the scrutiny of attention researchers. In this domain, it is not obvious which components of attention are affected by reward, and whether the effect involves general enhancement or is specific to discrete components of attention. Observers viewed brief displays of differentially colored letters and reported their identity. Each color signified a consistent monetary value and we measured the accuracy of identification under different color-pairing conditions. At the end of the session, observers were paid the balance earned during the experiment. By fitting a model based on the Theory of Visual Attention (Bundesen, 1990) to the data, we estimated processing speed, selectivity, visual short-term memory and the threshold for perception. Our primary hypothesis was that observers could, under data-limited conditions via brief exposure, distribute their attentional resources according to the value of the stimuli, i.e. that selectivity would be higher for high-value over lower-value targets. Importantly, our design was balanced so that the expected utility of uninformed guessing was zero, yielding no incentive to employ value-dependent response criteria. We also tested value-dependent effects on the capacity of visual-short term memory. Finally, we tested for motivational salience effects, by including conditions with color-contingent negative values. This gave an opportunity to compare high-gain with high-loss conditions. We found clear effects of value on selectivity when comparing high- and low-value conditions. When comparing equally valuable high-loss and high-gain conditions there were indications of risk-aversion, consistent with results from behavioral economics. We show that the expected value of target selection shapes the deployment of resources at very low exposure durations and can increase the capacity of VSTM in a paradigm untainted by post-perceptual effects.

33.502 **Object Long-Term Value and Novelty Create Incentive Salience Maps that Bias Eye Movements** Ali Ghazizadeh[1](alieghazizadeh@gmail.com), Okihide Hikosaka[1]; [1]Laboratory of Sensorimotor Research, National Eye Institute, National Institutes of Health

Quick detection of and orientation to objects with incentive salience are key for animal survival. Here we report that long-term reward history and novelty of objects strongly bias free viewing in the absence of any task instructions. Two adult male rhesus monkeys were trained with over 100 similar-looking fractal objects with which they had no prior experience. To create reward history, fractals were randomly associated with large or small reward in an object-directed saccade task over multiple days (good vs. bad objects). Long-term familiarity was established by free viewing or passive viewing of another set of fractals over multiple days with no reward association (neutral familiar objects). Test sessions consisted of trials in which animals freely viewed four random fractals in the absence of stimulus or behavioral contingent reward. In value block, fractals were randomly chosen from good or bad objects. In novelty block, they were randomly chosen from neutral familiar or completely novel objects. Upon display onset, majority of first evoked saccades were toward good or novel objects ($p<.001$). This indicates that objects long-term value and novelty are detected even at the periphery and evoke quick orienting responses (RT~200ms). Subjects viewed good or novel objects longer than bad or familiar objects ($p<.001$). Furthermore the rate of exploratory mini-saccades (<2.5 deg) within good or novel objects was significantly higher than within bad or familiar objects ($p<.001$). This shows that not only good and novel objects are salient (draw initial attention) but that they have incentive quality (are liked). Unlike good objects however, the novelty-driven incentive salience decreased over trials as objects became more familiar. Together these results show that the history of observer-object interactions creates incentive salience maps that guide saccades regardless of physical features and without any explicit targets.

33.503 **Attention capture by task-irrelevant learned value interacts with task-relevant top-down factors** Mary MacLean[1](mary.maclean@psych.ucsb.edu), Barry Giesbrecht[1,2]; [1]Institute for Collaborative Biotechnologies, University of California, Santa Barbara, [2]Psychological & Brain Sciences, University of California, Santa Barbara

Learned reward associations can capture attention even when they are non-salient, and task-irrelevant (e.g. Anderson et al., 2011; Raymond & O'Brien, 2009). This effect is generalizable (Anderson et al., 2012), persistent over long periods of time (Anderson & Yantis, 2013), interacts with salience (Anderson et al., 2011), and appears to be spatial in nature (Anderson & Yantis, 2012; Theeuwes & Bopolsky, 2012). Here we investigated how task-irrelevant learned reward associations interact with task-relevance both in terms of task set and space. In two experiments, multiple targets (letters) were briefly presented with an equal number of distracters (numbers) within task-relevant space equidistant from fixation. Another distracter ("flanker") was also presented outside of task-relevant space (Exp. 1 letter only; Exp. 2 letter, number, or symbol). A pattern mask followed the display. Participants performed a 2-AFC (probed target vs. lure). Each item was presented within a uniquely colored circle. The color of the circles was task-irrelevant. On a subset of trials the color of one circle had a previously learned reward association (reward circle). There were two critical effects. First, when the probed target was presented within the reward circle there was a benefit to target accuracy relative to when no reward circle was presented. When any other item was presented within the reward circle there was a cost. These results add to existing evidence that task-irrelevant learned reward associations result in the spatial capture of attention. Second, task-relevance, both in terms of task set and space, interacted with the spatial capture effects of irrelevant learned reward associations. Specifically, the effect of irrelevant learned reward association was larger for target items than distracters and larger for items within task-relevant space than outside of task-relevant space. Our findings suggest that the effects of task-irrelevant top-down factors (i.e. learned reward associations) on attention are mediated by task-relevant top-down factors.

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33.504 Reward directly modulates perception in binocular rivalry

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Although an influence of value on perception and attention is largely undisputed, the exact nature of the interaction between valuation, perception and attention is open. To probe effects of value on perception and their interaction with attention, we used binocular rivalry induced by gratings of different color drifting in opposing directions. To ensure that observers' perceptual experience was veridically measured, their optokinetic nystagmus was used as indicator of the currently dominant percept. One percept was rewarded or asked to be attended and the amount of reward was signaled by the width of a blue annulus surrounding both rivaling gratings. We found that dominance increased for the rewarded percept relative to the other, non-rewarded, percept. Since the effect of reward was similar to attending the respective stimulus, we next tested whether our results were effects of value per se, or merely mediated by a shift in attention to the rewarded grating. Observers were asked to perform an attentionally demanding task either on the rewarded stimulus, the other stimulus or both: participants detected changes in the duty-cycle of the respective grating, which were sufficiently subtle to not by itself cause a switch in dominance. We found that reward still modulated perception even if attention was held constant. This renders it unlikely that effects of reward are mediated solely by attention. To test whether attention can nonetheless selectively enhance perception according to value, we performed the same experiment with the same visual stimulus signaling penalty instead of reward. We found increased dominance durations for the non-penalized percept, which were similar to the effects of reward. Taken together, our data show that more valuable stimuli are selectively enhanced, but that value has a direct impact on perceptual representations even if stimuli and attention directed to them are held constant.

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33.505 The Value of Paying Attention

Carsten S. Nielsen[1](carsten.nielsen@psy.ku.dk), Anders Petersen[1], Claus Bundesen[1]; [1]Department of Psychology, University of Copenhagen

When acting in a dynamic environment we continuously trade-off the costs and benefits of attending to things. Valued-based attention thus helps us to bias the identification and selection of objects to which we assign a high value, and thus modulate both the processing speed and report accuracy of such. Here we put the hypothesis that monetary rewards can modulate speed and accuracy at the perceptual level to a test. Specifically, we test whether the utility of making specific visual categorizations can induce preferential processing. A Theory of Visual Attention (TVA; Bundesen, 1990) is used to inform the design of an experiment in which performance contingent monetary rewards are selectively associated with the identification of a briefly presented, mutually confusable single stimuli in a pure accuracy task. This allows us to investigate how the utility component of visual attention is modulated as a function of reward magnitude. Reward's impact on attention is evident in the experiment: When the rewards are high, neutral and low, the processing speed is increased, intermediate and reduced. No effect on the threshold at which the perceptual process begins is found. This suggests that rewards modulate the processing rate and report accuracy of stimuli identification, consistent with the idea that rewarded visual categorizations are processed preferentially.

33.506 Irrelevant Spatial Value Learning Modulates Visual Search

Jane Raymond[1](j.raymond@bham.ac.uk), Risa Sawaki[1]; [1]School of Psychology, University of Birmingham

Our sensory environment is replete with visual stimuli that are associated with motivational value. Growing evidence has demonstrated that the learned value of visual stimuli strongly influences visual processing. Although it has been shown that the learned value of a stimulus feature (e.g., object color) can modulate visual processing of items possessing that feature, it is unclear whether value associations pertaining to specific locations in space can modulate visual processing for other (untrained) stimuli presented at those locations when they are seen in a context for which prior spatial value learning is irrelevant. The present study investigated this issue by combining a spatial value learning task with a visual search task. Participants first learned to associate the presentation of a stimulus at one of four possible locations with a monetary outcome. Different locations were good or poor predictors of large or small wins (providing a unique probability X value combination for each location). Then, participants performed a simple visual search task involving four stimuli, one presented at each of the previously learned locations. Importantly, target location was non-predictive and no rewards were forthcoming, making location-outcome associations irrelevant. Nevertheless, we found that visual search was fastest for targets presented at the location previously associated with the best expected value. Spatial-value learning biases attentional orienting even when disadvantageous.

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33.507 Value-driven attentional capture resists extinction in adolescence

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Adolescence has been characterized as a period of both opportunity and vulnerability. Numerous clinical conditions ranging from mood and anxiety disorders to substance use disorders often emerge during adolescence. These maladaptive behaviors and psychological disorders have been linked to problems with cognitive control, yet few studies have investigated how rewards differentially modify attentional processes in adolescents versus adults. Here, we trained adults and adolescents on a visual task to establish stimulus-reward (S-R) associations. Later, we assessed learning in an extinction task where previously rewarded stimuli periodically appeared as distractors. Both groups initially demonstrated value-driven attentional capture; however, the effect persisted longer in adolescents. The results could not be explained by developmental differences in visual short-term working memory. Given the importance of attentional control to daily behaviors and clinical conditions such as ADHD, these results reveal that cognitive control failures in adolescence may be linked to a value-based attentional capture effect.

33.508 Brain signatures of reward-dependent bias in visual attention

Iris Wiegand[1](iris.wiegand@psy.ku.dk), Carsten Nielsen[1], Anders Petersen[1], Mads Dyrholm[1], Claus Bundesen[1]; [1]Center for Visual Cognition, Department of Psychology, University of Copenhagen

According to the Theory of Visual Attention (TVA), important visual features (features with a high valence) are processed more rapidly than unimportant ones. In the present study, we tested this assumption and assessed brain correlates of reward-dependent changes in visual processing by combining the formal framework of TVA with electrophysiology (EEG). We recorded EEG while participants completed a task in which accuracy of discriminating certain stimulus features was selectively associated with contingent monetary rewards. More specifically, the rewards for detecting Landolt ring gap locations on the diagonal and straight axes were varied across blocks, thereby abstracting valence from salience effects. We quantified performance using TVA-based fitting, and analyzed event-related potentials (ERP) and linear discriminant components to unveil brain mechanisms underlying behavioral changes related to reward. We found a higher processing rate for features associated with high reward relative to those associated with low reward. The behavioral effect was mirrored in multiple grand-average ERP modulations: The P1 was higher, and mid-latency central positivity was lower, when the to-be-discriminated feature's valence was high. A stronger medial frontal negativity (MFN) later in time was found for lower-rewarded features. The results suggest that sensory, attentional, and motivational processes contribute to the effects of reward on visual discrimination accuracy. On the single-trial level, we separated spatio-temporal components giving information about the dynamics of these processes. In accordance with TVA, we argue that a controlled setting of perceptual biases, such that important features are associated with stronger perceptual biases (β values), eases the encoding of features associated with high positive outcomes from early perceptual stages on.

33.509 Unreliable associations between visual features and values interfere with reward-based decision-making

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Many real world decisions depend on learning how visual characteristics of options predict their value. For instance, color is often predictive of food quality. Reinforcement learning (RL) models of such decisions often implicitly assume that only relevant, attended visual features play a role in decisions based on feature-value associations. How well are humans able to selectively attend to a given visual feature dimension to learn appropriate feature-value associations, while ignoring irrelevant feature-value associations? To assess this capacity, two experiments employed a 'four-armed bandit' task to assess whether learning of irrelevant feature-value associations intrudes on decision-making. In Experiment 1, four colors appeared on a screen in four locations, with the location of colors randomly determined on each trial. Participants selected a color option and then were monetarily rewarded or not based on a probability that varied independently for each option over time. Critically, reward probability was reliably associated with either color or location, and uncorrelated with the

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other dimension. Despite the fact that participants were fully informed of the relevant dimension, RL model comparisons suggest that they often inappropriately incorporated irrelevant and unreliable feature-value associations into their decisions. For instance, color-trackers inappropriately formed location-value associations, which played a role in decision-making. Since location was associated with motor responses, Experiment 2 randomized the binding of color, shape, and location of the 4 items, while participants attempted to track either color or shape while ignoring the other dimensions. Again, RL model comparisons suggested that participants often inappropriately incorporated irrelevant and unreliable feature-value associations into their decision-making (e.g., shape trackers inappropriately formed and employed color-value associations). These results suggest that visual feature-value associations are often formed even when the intent is to completely ignore a given dimension, perhaps as a means of maintaining flexible behavior in an uncertain environment.

33.510 Attentional Bias for Non-drug Reward is Magnified in Addiction

Brian A. Anderson[1](bander33@jhu.edu), Monica L. Faulkner[2], Jessica J. Rilee[2], Steven Yantis[1], Cherie L. Marvel[2,3]; [1]Department of Psychological and Brain Sciences, Johns Hopkins University, [2]Department of Neurology, Division of Cognitive Neuroscience, Johns Hopkins University, [3]Department of Psychiatry and Behavioral Sciences, Johns Hopkins University

Attentional biases for drug-related stimuli have been well documented in addiction and are related to treatment outcome. Attentional biases also develop for stimuli that have been paired with non-drug reward in adults without a history of addiction, the magnitude of which is predicted by visual working memory capacity and impulsiveness. We tested the hypothesis that addiction is associated with an increased attentional bias for non-drug (monetary) reward relative to that of healthy controls, and that this bias is related to working memory impairments and increased impulsiveness. Impulsiveness was measured using the Barratt Impulsiveness Scale (BIS-11), visual working memory capacity was estimated using a color change-detection task, and attentional bias was measured as the magnitude of response time slowing caused by irrelevant but previously reward-associated distractors in a visual search task (as in Anderson et al., 2011, PNAS). The results showed that attention was biased toward previously reward-associated distractors across both drug-dependent patients and healthy controls, replicating previous demonstrations of value-driven attentional capture. Importantly, this attentional bias was significantly greater in the patients than in the controls and was negatively correlated with visual working memory capacity. Patients were also significantly more impulsive than controls as a group. Our findings demonstrate that patients in treatment for addiction experience greater difficulty ignoring stimuli associated with non-drug reward. This non-specific reward-related bias could mediate the distracting quality of drug-related stimuli previously observed in addiction.

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33.511 Arousal Affects Attentional Guidance based on Selection History

Hannah Wyland[1](HCW2@geneseo.edu), Jeffrey Mounts[1], Matthew Hilimire[2]; [1]SUNY Geneseo, [2]College of William & Mary

Research has begun to examine whether emotional stimuli might influence attentional control settings. Here, we examine whether selection history biases, in the form of Priming-of-Popout (PoP), are influenced by the presence of emotional stimuli. In the PoP paradigm, a set of homogenous distractors (e.g., green) are displayed along with a target defined by a unique feature (e.g., orange). The features of the target and distractors varies across trials, with PoP defined as faster responses identifying the target when the target-defining feature repeats across trials compared to when it changes. In the first experiment, we induced a fearful or neutral context by briefly presenting a picture before the search display (170 ms SOA). The pictures depicted either interpersonal violence involving a weapon, or a picture of a neutral household object (e.g., a basket). The results indicated that PoP was significantly reduced in the fear context compared to the neutral context. A second experiment tested the generality of the effect, and ruled out an alternative explanation based on the nature of the neutral pictures. The neutral context pictures were low arousal, neutral valence pictures of people (rather than objects). The same fear inducing pictures (high arousal, negative valence) were used in the fear context, while a third context depicted people in thrilling scenes (high arousal, positive valence; e.g., skydiving). Compared to the neutral context, PoP was significantly reduced following both the fear and thrill context pictures, suggesting that PoP reduction is controlled by arousal, rather than valence. However, it is possible that despite their positive valence, the thrill pictures may have also induced a level of fear due to the dangerous nature of the situations depicted. Regardless, the results suggest that selection history biases may be temporarily reset by emotional stimuli, allowing the more efficient selection of new information in such circumstances.

33.512 Attentional capture from emotional associations in long-term memory

Jonas Everaert[1, 2](jonas.everaert@ugent.be), Judith E. Fan[1], Ernst H.W. Koster[2], Nicholas B. Turk-Browne[1]; [1]Department of Psychology, Princeton University, United States of America, [2]Department of Experimental-Clinical and Health Psychology, Ghent University, Belgium

Cognitive processes such as attention and memory are closely related to one's emotional state: Healthy individuals pay more attention to and better remember positively valenced stimuli, whereas anxious and depressed individuals are biased toward negatively valenced stimuli. Although such biases are well-documented, the underlying mechanisms are unclear. Here we examine how emotional associations in long-term memory guide spatial attention. In an initial encoding phase, distinct colors were consistently paired with faces depicting either happy, neutral, or angry expressions while participants performed a gender-discrimination cover task. In a subsequent test phase, two lines were presented on each trial, one tilted away from vertical (target) and the other vertical (distractor), and participants located the target's position. Colored disks framed each line: one color was associated with happy or angry faces and the other was associated with neutral faces. Colors associated with emotional faces framed the target (valid) and distractor (invalid) with equal probability, and target location was randomized — colors were thus completely task-irrelevant. Attentional capture was quantified as invalid minus valid RT for a given valence category. We found that attentional capture for colors associated with happy faces was significantly predicted by subsequent memory for these color-expression associations. This was not true for colors associated with angry faces, suggesting a dissociation between attentional guidance from positive vs. negative information. Interestingly, individual differences in depression and anxiety levels were negatively correlated with the degree of attentional capture by colors associated with happy faces (e.g., more depressed individuals showed less capture from stimuli with positive associations). Taken together, these findings contribute to our understanding of how basic cognitive processes are modulated by emotion in both healthy and clinical populations. Namely, negative biases in anxiety and depression do not merely reflect motivational or decisional factors, but partly arise from more automatic forms of attentional capture.

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33.513 Pavlovian Conditioning and the Koniocellular Pathway Using Steady-State-Evoked Potentials

Nathan Petro[1](npetro@ufl.edu), Vladimir Miskovic[2], Andreas Keil[1]; [1]Department of Psychology, University of Florida, [2]Department of Psychology, Binghampton University

Many studies suggest that sensory cortical responses to affectively engaging arousing stimuli are amplified, compared to neutral stimuli. Past research demonstrates gradually increased electrocortical facilitation of lower-tier visual signals with acquired relevance, through classical differential Pavlovian conditioning. The neural mechanism mediating these changes is not known however. One potential avenue to addressing this problem are studies examining the sensitivity of specific visual pathways to learned motivational relevance. Here, steady-state-evoked potentials were used to test whether visuocortical neural mass activity responded differentially to conditioned motion direction cues paired or unpaired with a loud noise. Using this design, we investigated the extent to which luminance-based and koniocellular-based stimuli are differentially sensitive to visual motion kinematograms predictive or not predictive of the noxious unconditioned stimulus. Koniocells were uniquely activated using a yellowish-hue based adaptation procedure designed to isolate s-cones, while a luminance stimulus type served as a control. Both stimulus types evoked greater neural activity when paired with a US. Overall the koniocellular-biased stimulus displayed an overall higher steady-state power. These results demonstrate that neurons coding visual motion information respond to Pavlovian conditioning. While the koniocell pathway did not show a unique effect of motion conditioning, the overall greater steady-state power warrants further exploration.

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33.514 **Saccade trajectories are immediately curved in accordance with the degree of threat from task-irrelevant stimuli** Yoshiyuki Ueda[1](ueda@educ.kyoto-u.ac.jp), Masato Nunoi[2], Kenshiro Ichimura[2], Yuki Shirasuna[2], Masahiro Fujino[3]; [1]Kokoro Research Center, Kyoto University, [2]Graduate School of Education, Kyoto University, [3]Faculty of Education, Kyoto University

Previous research has demonstrated that a task-irrelevant threat-related face which is presented peripherally influences spatial attention and oculomotor control (e.g., Schmidt, Belopolsky, & Theeuwes, 2012; Ueda & Yoshikawa, 2012). Accurate attention allocation to threat-related stimuli is crucial for survival; therefore, the type and direction of a facial expression is important. However, the immediate information obtained from peripherally presented faces, as well as a plan for action based on this information, is not well known. We examined the effect of head direction and emotion of task-irrelevant faces on saccadic eye movements. A central fixation cross was presented with two additional crosses, which were located above and below the fixation. After a random interval between 800 and 1300 ms, the central cross changed into either an upward or downward arrow; participants moved their eyes to the additional cross as directed by the arrow as quickly and accurately as possible. While the central cross changed, one facial expression and one neutral object were presented as distractors to the left and right of the midpoint between the central and the above/below crosses. In half of the trials, the distractor face was oriented straightforward (direct condition) whereas in the other trials, the face was directed 45° away from straightforward (averted condition). Results from saccade trajectories showed that participants were more likely to move their eyes while curving away from angry faces rather than the happy faces regardless of direction. Moreover, saccade trajectory curvatures were diverted more away from both direct angry and happy faces than from averted faces. These results suggest that recognition of peripheral faces achieved by accurate and immediate processing of facial expressions and head direction produces immediate oculomotor control.

33.515 **Not All Threats are Created Equal: Selection History Biases are Differentially Affected by Fear and Disgust** Matthew Hilimire[1](mrhilimire@wm.edu), Jeffrey Mounts[2], Bina Kakusa[1]; [1]Psychology Department, College of William & Mary, [2]Psychology Department, State University of New York at Geneseo

Recently, there has been a growing interest in examining how implicit memory factors, such as selection history, guide visual attention. One manifestation of selection history is intertrial feature priming, which is observed when reaction times to a target decrease when properties defining the target and/or distractor repeat across trials compared to when they change. The current study examined the influence of threat on intertrial priming. Prior to a visual search display, a threatening, neutral, or inverted neutral image was presented. Between groups, the threatening images were either fear-inducing (e.g., guns, knives, snakes) or disgust-inducing (e.g., roaches, mutilations). The length of time that the image was presented was manipulated (150, 250, 1000, and 1500ms). In the visual search task, the target was one of two color singletons (one orange, one green) presented among grey filler objects. Each object was a circle outline that contained a caret. The target singleton contained a caret from the target set (pointing left or right), whereas the decoy singleton contained a caret from the non-target set (up or down). The color of the target changed randomly trial-to-trial. Observers responded to the orientation of the caret inside the target singleton. When the fear-inducing image was presented for 150 ms, reverse priming occurred (i.e., reaction time was faster when the target color switched from the previous trial compared to when the target color repeated). This was due to slowing of reaction time on target color repeat trials for the fear context relative to the neutral context. In contrast, the disgust-inducing images resulted in typical patterns of priming. These results support the idea that fear triggers a type of attentional reset, clearing previous selection biases in order to more effectively attend to and process new potential threats in the environment.

Attention: Neural mechanisms and modeling

Sunday, May 18, 8:30 am - 12:30 pm
Poster Session, Pavilion

33.516 **Attention to color in the primate Superior Colliculus** James Herman[1](hermanj@gmail.com), Richard Krauzlis[1]; [1]Laboratory of Sensorimotor Research, NEI, NIH

Activity in the intermediate layers of the primate Superior Colliculus (SC) is known to reflect the occurrence of behaviorally relevant visual events, even in the absence of orienting movements. Until recently, it was also believed that visual activity in the SC was largely color-blind. Here we tested whether color-related signals in the SC, which likely originate in the cerebral cortex, might also be exploited to detect behaviorally relevant, but purely chromatic, changes in the visual environment. We recorded the activity of neurons in the superficial and intermediate layers of the SC during a covert attention task employing dynamic “checkerboard” color stimuli described previously (Herman et al., 2013). The animal was presented with two color stimulus patches (3.25° radius, ~10° eccentricity) while maintaining central fixation and pressing a joystick. Prior to stimulus onset, a ring was flashed, cueing one of the two upcoming stimulus locations. The task was to respond to a change in saturation by releasing the joystick for changes at the cued location, and ignoring changes at the opposing “foil” location. Color changes were physically isoluminant, masked with luminance noise, and adjusted to be near the monkey’s detection threshold. Most neurons showed dramatic, rapid increases in activity (latency 110-150ms) triggered by the color changes. Though the changes were near the animal’s detection threshold, the activity they evoked was ~60% greater than the activity evoked by stimulus onset. Activity was also greater for changes that were detected than for those that were missed. Consistent with previous work, SC neurons showed a robust cueing effect – in most neurons (13/19 to date), we observed significantly greater activity for the cued stimulus compared to the foil. These results demonstrate that SC activity signals behaviorally relevant events even when those events involve color features distinctive of the primate visual system.

33.517 **Neuronal correlates of change detection in Superior Colliculus during covert spatial attention** Anil Bollimunta[1](anilbollimunta@gmail.com), Richard Krauzlis[1]; [1]Laboratory of Sensorimotor Research, National Eye Institute, Bethesda, MD.

Inactivation of the intermediate layers of the Superior Colliculus (SC) causes deficits in covert spatial attention (Lovejoy & Krauzlis, 2010). However, these deficits are not accompanied by corresponding changes in attentional modulation in the cortex (Zenon & Krauzlis, 2012). To clarify the neuronal mechanisms through which SC controls covert attention (Krauzlis et. al., 2013), here we tested how the activity of SC neurons is modulated during an attention task requiring the detection of a change in the direction of a motion stimulus. Rhesus macaques were trained to report a change in the direction of motion at a cued location, while ignoring changes at a foil location, by releasing a lever during maintained fixation. The stimuli were random dot motion patches and the change in direction was set to be near threshold. Receptive fields (RF) of SC neurons were mapped using a delayed visually guided saccade task, and one of the two motion patches was placed within the RF during the motion direction change detection task. SC neurons showed transient increases (decreases) in firing rate when the change happened inside (outside) the RF. (1) This transient signal appeared as early as ~120 ms after change onset. (2) The firing rate, after change onset, was higher for correct responses than for misses when the change happened within the RF. (3) The firing rate increased earlier for shorter reaction times (RTs) than for longer RTs. These results show that, in addition to the sustained changes in activity found with spatial cues, SC neurons also exhibit transient changes related to detection of behaviorally relevant events. Inactivation of SC could disrupt this ‘change-detection activity’ causing behavioral deficits during covert attention tasks that have been previously reported (Zenon & Krauzlis, 2012).

33.518 **Neuronal correlates of change detection in Basal Ganglia during covert spatial attention** Fabrice Arcizet[1](f.arcizet@gmail.com), Richard Krauzlis[1]; [1]Laboratory of Sensorimotor Research, National Eye Institute, Bethesda, MD.

Detecting changes in the visual environment is crucial for normal behavior and is a central element of most spatial attention tasks. The behavioral relevance of changes, and deciding which action should follow, also depends on the context. Here we investigated how neuronal activity in the caudate

Sunday AM

nucleus, one of the major input structures of basal ganglia, is related to the evaluation of stimulus changes during an attention task. We examined the responses of caudate neurons while a rhesus macaque performed a motion-change detection task. While fixating centrally, a spatial cue was flashed centered on the response field of the neuron or in the opposite hemifield. Two motion patches were then presented – one inside and one outside the neuron's response field. In some trials, the cued motion patch changed direction, and the monkey had to release the joystick within 700 ms to be rewarded. In other trials, the direction change happened at the non-cued location and the animal was rewarded for not releasing the joystick. We recorded from 83 medium spiny neurons in the caudate during the task. A subset of neurons showed significantly elevated activity time-locked to the motion-direction change, indicating the presence of a change-detection signal. This activity was not simply a visual response, because activity was significantly higher when the monkey responded correctly to the change by releasing the joystick (hits) than when he mistakenly failed to release (misses). Moreover, the modulation was correlated with reaction times – it started earlier when the animal responded more rapidly to the motion change. These results show that neurons in the caudate exhibit activity related to behaviorally relevant visual changes. The finding that this activity depends on the behavioral context and the animal's performance suggests that the caudate nucleus could form a functional bottleneck during spatial attention tasks.

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33.519 **Comparison of superior colliculus and primary visual cortex in the coding of visual saliency** Brian White[1](brian.white@queensu.ca), David Berg[2], Takuro Ikeda[1], Ron Levy[1], Laurent Itti[3], Douglas Munoz[1]; [1]Centre for Neuroscience Studies, Queen's University, [2]IBM Research, San Jose, California, [3]Department of Computer Science, University of Southern California

The superior colliculus (SC) is a phylogenetically ancient midbrain structure with purely visual representations in the superficial-layers (SCs), and sensorimotor representations linked to the control of eye movements/attention in the intermediate-layers (SCi). In primitive species, SC played a central role in vision and orienting independent of cortex. Through mammalian evolution, primary visual cortex (V1) introduced more specialized feature processing, but also became a dominant source of input for SCs. We quantified the relative roles of these early visual areas in the coding of higher-order stimuli that give rise to saliency in complex scenes. Rhesus monkeys viewed a wide-field arrangement of stimuli (210 radially-arranged items spanning ~40-50deg) extending beyond the classic receptive field (RF). The stimuli were oriented color bars (~0.4x1.2deg) that formed a perceptual "pop-out" array the monkeys had to ignore; i.e., reward was contingent upon gaze directed to a separate achromatic stimulus that always stepped orthogonal to the pop-out singleton. We compared visually-evoked responses when the goal-irrelevant pop-out singleton fell in versus opposite the RF, and compared it to a single-item control condition. First, visual onset latency was reliably earlier, and RFs 5-10 fold smaller, in V1 than SCs (or SCi). This is consistent with the idea that each SCs neuron might integrate the outputs of multiple V1 neurons. Second, surround suppression evoked by the wide-field array was dramatically stronger in SCs (and SCi) than V1. This indicates the prominence of long-range interactions in SC, an essential component of the saliency-map hypothesis. Lastly, only SCs neurons showed a reliable preference for the goal-irrelevant pop-out singleton; in SCi stimuli were heavily suppressed unless made goal-relevant. From these observations, we propose that V1 fits the role of a local feature processer, SCs a bottom-up saliency map, and SCi a priority map shaped by a combined representation of bottom-up saliency and top-down relevancy.

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33.521 **Macaque monkeys exhibit event-related potentials indexing distractor suppression during visual search** Joshua Cosman[1,2,3](joshua.d.cosman@vanderbilt.edu), Jeffrey Schall[1,2,3], Geoffrey Woodman[1,2,3]; [1]Vanderbilt University Department of Psychology, [2]Vanderbilt Center for Integrative and Cognitive Neuroscience, [3]Vanderbilt Vision Research Center

Recent work has demonstrated that a specific event-related potential (ERP) component, the distractor positivity (Pd), indexes distractor suppression during visual search. Here, we provide the first evidence for a homologous component in nonhuman primates. Monkeys performed an adapted version of the additional singleton paradigm in which they searched for a shape pop-out target while ignoring a task-irrelevant color singleton distractor. Critically, targets and distractors could appear either along the vertical midline or at lateralized positions, allowing us to isolate and measure lateralized ERP activity related to targets or distractors. When the target appeared at lateralized positions (and the distractor on the vertical midline), a robust N2pc was observed, indicating selection of the target. However, when the distractor appeared at lateralized locations (and the target appeared on the midline) a reliable Pd was observed, indicating suppression of the distractor. This suggests that homologous mechanisms of distractor suppression operate in humans and nonhuman primates, and provides a basis for neurophysiological studies designed to determine the neural generators of the Pd component and distractor suppression during visual search.

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33.522 **Decoding the allocation of visual attention from prefrontal neural assemblies in behaving primates** Sebastien Tremblay[1](sebastien.du.tremblay@mail.mcgill.ca), Florian Pieper[2], Adam Sachs[3], Julio Martinez-Trujillo[1]; [1]Cognitive Neurophysiology Laboratory, Department of Physiology, McGill University, Montreal, Canada, [2]Institute for Neuro- & Pathophysiology, University Medical Center Hamburg-Eppendorf (UKE), Hamburg, Germany, [3]Division of Neurosurgery, Department of Surgery, The Ottawa Hospital Research Institute, University of Ottawa, Ottawa, Canada

The primate prefrontal cortex is thought to play an important role in intelligent goal-directed behaviour. Single neurons in different regions of the PFC are tuned for the allocation of attention as well as for the final position of saccades. Here we show that the activity of a small population of simultaneously recorded neurons from macaque PFC area 8a can be reliably decoded to signal the allocation of attention to one of four Gabor stimuli presented on a computer screen with 71% accuracy, and the goal of a saccade to the same stimulus with 95% accuracy. The presence of a transient change in one of the unattended distracters slightly decreased the coding accuracy by 25%, demonstrating that the encoding was robust to interference by transient distracter changes. Moreover, the population code was equally reliable when we used the pooled multiunit activity of single electrodes rather than the sorted single unit activity. Importantly, the code was constant across a timespan of multiple weeks, suggesting a stable functional network architecture underlying the coding of attention and saccade goal. Our results demonstrate that the activity of a small population of neurons, distributed over an area of ~16 mm2 of PFC, contains sufficient information to decode the allocation of spatial attention as well as the goal of a saccade with high accuracy, robustness, and stability over time. They suggest that PFC area 8a could be a target for brain machine interfaces (BMI) that take into account the relevance of environmental stimuli to produce goal-oriented behaviour.

33.523 **Task-relevant or Task-irrelevant: Is Allocation of Attention Based on Fast and Precise Location Information?** Søren Kyllingsbæk[1](sk@psy.ku.dk), Claus Bundesen[1], Barry Giesbrecht[1,2]; [1]Department of Psychology, University of Copenhagen, [2]Department of Psychological & Brain Sciences, University of California, Santa Barbara

The allocation of visual processing capacity is a key topic in studies and theories of visual attention. The Load Theory of Lavie (1995) has proposed that allocation happens in two stages where processing resources are first allocated to task-relevant stimuli and then remaining capacity 'spills over' to task-irrelevant distractors. Kyllingsbæk, Sy, and Giesbrecht (2011) previously showed that the two-stage allocation scheme is not valid and instead showed that processing capacity is allocated in a single step. Here we test another critical assumption made by Load Theory: task-relevant and task-irrelevant stimuli are sharply distinguished, usually based on spatial location, and this information is accurate and computed rapidly before the two-stage capacity allocation scheme is engaged. To test this assumption, six participants performed a flanker search task that varied in load (e.g., Lavie & Cox, 1997). We then constructed two models based on the Neural Theory of Visual Attention (Bundesen, Habekost, & Kyllingsbæk, 2005). The first model embodied the Load Theory assumption, such that location information was available immediately. In the second model, location information was processed in parallel with the processing of stimulus identity. Contrary to Load Theory, we find that the second model in which location information distinguishing task-relevant and task-irrelevant stimuli from each other is processed slowly provided a more accurate fit of the data. Our alternative model provides a detailed computational account of how bottom-up and top-down information is integrated to provide efficient attentional selection and allocation of perceptual processing resources to task-relevant and task-irrelevant information.

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33.524 **Deriving the acuity and the capacity of visual spatial attention** George Sperling[1](sperling@uci.edu), Arvin Hsu[2]; [1]Department of Cognitive Sciences, University of California, Irvine, [2]Department of Cognitive Sciences, University of California, Irvine

To measure the acuity of visual attention, a search target is placed in one of several to-be-atttended areas surrounded by unattended areas filled with false targets. Shaping the attended areas into gratings of different spatial frequencies enables a Fourier Analysis derivation of the spread function of spatial attention. The assumptions are: all stimulus elements are represented in perception with a certain amount of random error, targets and false targets have an incrementally greater mean perceptual strength s than distracters, s is attenuated according to the spatial frequencies of the attended-unattended area arrangement. A Fourier-derived attention spread function accurately accounts for the performance of observers in the 20 such grating displays used to derive it. To test the theory, observers were trained to detect targets in new displays in which to-be-attended areas of were randomly generated. In moderately complex random displays, the Fourier theory, with one new "difficulty" parameter predicted performance in the 72 (of 144) attended locations. Ultimately, in still more complex displays, observers partially or completely neglected certain to-be-areas thereby indicating capacity limits of attention that depend both on the number of areas to-be-attended and the shape-complexity of the to-be-attended areas.

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33.525 **What Does it Mean to Better Attend?** John Tsotsos[1,2](tsotsos@cse.yorku.ca); [1]Dept. of Electrical Engineering and Computer Science, York University, [2]Centre for Vision Research, York University

We present a proposal to answer: how could an agent learn to better attend to the relevant and ignore the irrelevant in the context of performing visual tasks? To answer this, attention is defined as in Tsotsos (2011): Attention is the set of mechanisms that tune and control the search processes inherent in perception and cognition, dynamically adapting a general purpose processor to the input and task of the moment. To improve one's attention means that tuning and search control become more effective, e.g., task performance shows improvements in speed and accuracy. The link between this definition of attention and such improvements lies in the computational foundations underlying the Selective Tuning (ST) attentional theory, namely computational complexity (Tsotsos et al. 1995; Tsotsos 1990, 2011). Suppose one compares two algorithms, both effective for the same problem. The one with lower time complexity will lead to a faster solution. Lower time requirements can be achieved by reducing the number of candidates to consider via task-driven suppression or grouping. Given the same amount of time, two algorithms can be compared in terms of their accuracy. The more accurate algorithm will have improved decision-making mechanisms, perhaps by reducing the impacts of noise, ambiguity, or number of potential choices of action, or by eliminating interfering computations. For example, stronger suppression of distractors may reduce the impact of noise. The set of attentive mechanisms (selection, suppression and restriction and their 15 sub-classes) within ST are each examined and their variations with respect to performance (time and accuracy) are built into an overall optimization criterion that drives any changes due to experience. A Hebbian learning strategy is used to combine the minimization of time complexity while maximizing accuracy in a neurobiologically plausible manner. Finally, we point to experimental work that might verify the proposal.

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33.526 **Visual Attention in Dynamic Environments and its Application to Playing On-line Games** Yulia Kotseruba[1, 2](yulia.kotseruba@gmail.com), John Tsotsos[1, 2]; [1]Department of Electrical Engineering and Computer Science, York University, [2]Centre for Vision Research, York University

We examine the visual processing requirements of complex visual tasks by building a system capable of playing Jump'n'Run on-line games (e.g. CANABALT - http://www.adamatomic.com/canabalt) in real time. Such games are visually complicated while gameplay remains simple - move the character as far as possible in the map and help it avoid obstacles by pressing a single button. In our setup, video is streamed from the camera pointed at the monitor and button press is controlled by computer. The current gaze position imposes a fovea and periphery in each frame. The theoretical foundation for our work is the Selective Tuning model of visual attention (Tsotsos 2011) and the accompanying Cognitive Programs framework (Tsotsos 2013). We implement relevant parts of the model and show how it enables interaction between the high-level knowledge of the game and low-level context-independent algorithms used for bottom-up image processing. Since our focus is visual attention, we did not learn gameplay logic and instead hard-coded Cognitive Programs as a hierarchy of Finite State Automata: each FSA is composed of elements that in turn are decomposed into FSA's. These include detection and tracking of characters/obstacles, edge/line detection, construction of saliency maps, selection of regions of interest, foveation, changing gaze position, decisions regarding visual contents, spatial relations, etc. We learn game physics by using regression analysis to find relationship between the duration of the button press and sampled jump trajectories. We show that this representation is sufficient for this task and that the inclusion of attentive mechanisms permits us to achieve real-time performance. In particular, several elements help optimize vision algorithms by reducing the search space and partially eliminate image artefacts introduced by the camera. Based on the current state of the game we are able to make assumptions about the next events and adjust the image processing hierarchy accordingly.

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33.528 **Vision as a three-stage process: encoding, selection, and decoding** Li Zhaoping[1](z.li@ucl.ac.uk); [1]Computer Science Department, University College London, UK

Traditionally, vision has been seen to comprise low-level, mid-level, and high-level processes. To make computational tasks explicit and highlight the central role of visual attention, I propose to view vision as having the encoding, selection, and decoding stages. These three stages do not correspond to the low-level, mid-level, and high-level vision, although the encoding stage dominates in low-level vision. At encoding, representation of visual information is transformed for some purposes, e.g., photoreceptor signals are transformed to retinal ganglion responses, such that a maximum amount of input information is sent to the brain while limiting the cost on neural resources (e.g., information bandwidth at the optic nerve). At selection, a tiny fraction of visual information is admitted into the attentional bottleneck for detailed processing. For example, a spatial location is selected through a saccade towards it for scrutiny, while information at other locations are downplayed or deleted. Selection can be exogeneous when a saliency map created in the primary visual cortex (V1) guides selection by its monosynaptic projection to the superior colliculus (SC) which executes saccades. Selection can also be endogenous when, e.g., the knowledge about the location of our book guides our gaze, controlled largely by frontal and parietal brain areas which also project to SC. At decoding, properties of visual scenes, e.g., the identity and movement of an object, are inferred to become our perception and aid our movements, from a combination of the information admitted to the attentional bottleneck and internal knowledge or expectation of the visual environment. In the first approximation, encoding, selection, and decoding stages are assumed to occur consecutively along the visual pathway. Hence, exogeneous selection by V1 suggests decoding and endogenous selection by extrastriate cortices. However, feedback between stages, especially between selection and decoding, are expected to enable process iterations to improve vision.

Acknowledgement: The Gatsby Charitable Foundation

Attention: Divided

Sunday, May 18, 8:30 am - 12:30 pm
Poster Session, Pavilion

33.529 **Dual-task backward compatibility effects are episodically mediated.** Maria Giammarco[1](agiammar@uoguelph.ca), Sandra Thomson[2], Scott Watter[3]; [1]University of Guelph, [2]McMaster University, [3]McMaster University

Navigating successfully through our visual environment often requires the efficient co-ordination of multiple tasks, and understanding how we accomplish such multi-tasking behaviours is necessary for optimizing our performance in these situations. In the current work, we investigated dual-task performance using the backward compatibility effect (BCE) present in the Psychological Refractory Period (PRP) paradigm: When performing two tasks, Task1 reaction times (RTs) are faster if Task1 and Task2 responses are compatible. The BCE is believed to provide evidence that Task2 response information is automatically activated in parallel with Task1 response selection, however, the mechanisms through which this effect arises have been debated. Hommel & Eglau (2002) proposed a central role for episodic processes, whereas Ellenbogen & Meiran (2008) provided evidence that Task2 rules held in working memory facilitate parallel processing. Through two multipart experiments utilizing a visual PRP paradigm, we demonstrate a dissociation of these conflicting theories, and provide novel evidence in favour of an episodic model. In Experiment 1 we observed the selective development of BCEs following varying degrees of prior single-task practice. These results confirm the predictions of an episodic model, and contrast those of a working memory model: both BCEs and overall improvements in RT should occur, regardless of the context of prior practice. In Experiment 2 we further examined the time course of the development of BCEs through initial BCE development, followed by interference of initial learning on BCE development (through the introduction of novel, conflicting Task2 rules), and finally the re-establishment of BCEs through implementation of the original task. The presence of selective proactive interference effects from prior learning again provides evidence in favour of an episodic model. This work clarifies the role of episodic mechanisms in aiding efficient, parallel processing, while considering the role of working memory in contributing to additional aspects of dual-task performance.

33.530 **Too Much, Too Slow, or Too Flexible?Exploring The Influence of Task Difficulty on the Attentional Blink.** James Elliott[1,2](elliott@psych.ucsb.edu), Tom Bullock[1,2], Barry Giesbrecht[1,2]; [1]Department of Psychological and Brain Sciences, [2]Institute for Collaborative Biotechnologies

Three accounts have been proposed to explain the influence of first target (T1) difficulty on the Attentional Blink (AB). The processing speed account (PSA; Visser, 2007) suggests that increasing T1 processing time increases the severity of the AB. Furthermore, the PSA suggests that the inclusion of a T1-mask prevents T1-difficulty from influencing the AB. The resource allocation account (RAA; Shore et al., 2001) suggests that T1-difficulty only influences the AB when resources are allocated prior to the start of the trial, and therefore should only be observed when T1-difficulty is blocked. Finally, the flexible selection account (FSA; Giesbrecht et al., 2007; 2009) suggests that T1-difficulty should decrease processing of subsequently presented information. We test the key predictions of these three accounts in two experiments using a standard RSVP task that evokes an AB (e.g., Chun & Potter, 1995) and in which T1-difficulty was manipulated using noise dots presented simultaneously with T1. In experiment 1, T1-difficulty increased the severity of the AB ($F(5,65)=3.166$, $p = .033$) even though T1 was always masked and T1-difficulty was intermixed. This result is inconsistent with both the PSA and the RAA. In experiment 2 we examined the influence of T1-difficulty on lag-1 sparing. While neither the RAA nor the PSA suggest that T1-difficulty should influence lag-1 performance, the FSA predicts that bottom-up differences in T1 processing partially determine the influence of T1-difficulty on the AB. Therefore, differences should be observable as soon as T1-processing commences. As predicted by FSA, increasing T1-difficulty increased the severity of the AB ($F(5,100) = 3.122$, $p = .02$) and decreased accuracy at lag-1 ($t(20) = 5.016$, $p <.001$). These results support the FSA of T1-difficulty, which suggests that attention during the AB is flexible and that T1-difficulty is one factor that modulates this flexibility.

33.531 **Failures to filter: A marker of repetition suppression to task-irrelevant backgrounds predicts attentional lapses** Francesca Fortenbaugh[1], Monica Rosenberg[1,2], Joseph DeGutis[1], Sarah Noonan[1,3], Michael Esterman[1,4]; [1]V.A. Boston Healthcare System, BALLAB, [2]Department of Psychology, Yale University, [3]V.A. Puget Sound Healthcare System, [4]Department of Psychiatry, Boston University School of Medicine

While failures of selective attention to filter extraneous information are known to cause deficits in behavioral performance, to what extent are such failures reflected in neurophysiological measurements? This fMRI study tested 14 participants who completed a gradual continuous performance task (gradCPT). At the center of the display, faces morphed from one into the next at a rate of 1sec. Participants completed a go-no go task on these faces. Concurrently, task-irrelevant scenes were presented surrounding the faces, morphing from one to the next at a rate of 2.25sec. Participants completed three 8.4minute runs. Across each run, seven scene cycles were presented, each consisting of 16 presentations of novel scenes followed by 16 presentations of two alternating scenes (Period = 72sec, Repetition Frequency=0.0139Hz). Reduced BOLD activity to repeated presentations (repetition suppression) is viewed as a marker of perceptual processing. To assess the influence of repetition suppression induced by task-irrelevant scenes we employed a novel approach, conducting a coherency analysis on the repetition frequency. Results show consistently high coherence in classic scene-selective regions where repetition suppression of repeating scenes was expected. We then correlated the power at the repetition frequency with behavioral performance across three groups of independently localized ROIs: 1) scene-selective, 2) face-selective, and 3) gradCPT task-related. Higher coherence in extrastriate scene-selective ROIs was associated with higher error rates ($R=0.71$, $p=0.002$) and correct RT variability ($R=0.68$, $p=0.003$). Similar correlations between behavioral performance and power in frontal eye fields were also found. Lack of behavioral correlations with PPA ($R=0.08$) indicates that higher average coherence itself does not drive these associations. Further confirmation of the regional specificity of this relationship was found using a whole-brain voxel-wise regression analysis correlating behavioral performance with coherency results. These results show that reduced filtering of extraneous information across networks engaged by a task is associated with performance deficits.

33.533 **Perceptual and response related visual attention in children with ADHD** Ida Dyhr Caspersen[1](Ida.dyhr@psy.ku.dk), Signe Vangkilde[1], Lone Kelkjær[2], Kerstin von Plessen[2], Thomas Habekost[1]; [1]Department of Psychology, University of Copenhagen, Denmark, [2]Center for Child and Adolescent Psychiatry, Bispebjerg, Copenhagen, Denmark

Attention-Deficit/Hyperactivity Disorder (ADHD) continues to be one of the most prevalent childhood psychiatric disorders. Perceptual aspects of attention function in ADHD have been extensively studied by means of speed-based measures. However, taking into account the potentially impaired fine motor coordination and reduced ability to regulate the speed-accuracy trade-off often described in the ADHD-literature, reaction time based testing should be accompanied by accuracy-only tests which clearly distinguish perceptual from response-related components of attention. In the present study, we used an unspeeded verbal-report paradigm based on the Theory of Visual Attention (TVA, Bundesen, 1990) to measure parameters of visual attention in 24 children with ADHD, 20 clinical controls with autism spectrum disorder, and 55 healthy controls. TVA measures included visual processing speed, capacity of visual short-term memory, and the threshold of visual perception. In addition, we used a continuous performance test, the Dual Attention to Response Task (Dockree et al., 2006) to measure error rates, attentional lapses and reaction time. The two tasks were functionally specific and have previously proven sensitive to discrete group differences (Caspersen & Habekost, 2013). Children with ADHD showed significantly reduced visual processing speed compared to controls, whereas children with autism had a smaller short-term memory capacity. Moreover, compared to controls, ADHD was associated with significantly worse performance on several measures of sustained attention, including more errors of commission/omission, and more variation in reaction time. The only difference between clinical groups was a significantly higher frequency of attentional lapses among children with ADHD. Overall, the study demonstrates the strength of the TVA framework in specifying and quantifying the cognitive profile of ADHD. Results suggest a potential for TVA-based testing to contribute to differential diagnostics of co-morbid disorders, which is crucial for the on-going work of mapping clinically important endophenotypes.

33.534 **Inter-individual differences in preferred directions of perceptual and motor decisions** Alexander C. Schütz[1](alexander.c.schuetz@psychol.uni-giessen.de); [1]Abteilung Allgemeine Psychologie, Justus-Liebig-Universität Gießen, Germany

Perceptual and motor systems can be faced with ambiguous information and then have to choose between different interpretations or reactions. Often these alternatives involve decisions about directions and anisotropies have been reported for different tasks. Here we measured inter-individual differences and temporal stability of directional preferences in eye movement, motion perception and finger movement tasks. In all tasks, stimuli were created such that observers had to decide between two opposite directions in each trial. Preferences were measured at 12 axes around the circle. In saccade and finger tasks, subjects had to move either their eyes or an analog joystick to one of two stationary stimuli, displayed at opposite locations in the visual field. In a pursuit task, subjects had to pursue one of two overlapping random-dot-kinematograms, moving in opposite directions. In two perceptual tasks, subjects had to indicate the perceived motion direction of ambiguous apparent motion or structure-from-motion stimuli. There were clear directional preferences in all tasks. The strongest effects were observed in tasks that involved motion, like smooth pursuit eye movements, apparent motion and structure-from-motion. The weakest effects were observed in the saccadic eye movement task. Although there were consistent preferences across observers in some of the tasks, there was also considerable variability in preferred directions between observers. These individual preferences were stable over twelve weeks. Observers with strong directional preferences in the saccadic and smooth pursuit eye movement tasks had shorter latency costs for trials with two targets compared to trials with one target. These results show that individually stable directional preferences exist in a range of perceptual and motor tasks. The latency benefits for observers with strong preferences suggest that directional preferences are advantageous for solving target conflicts.

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Sunday AM

33.535 Blur Detection Is Unaffected By Cognitive Load, But Eye Movements and Scene Recognition Memory Are. Ryan V. Ringer[1](rvringer@ksu.edu), Aaron Johnson[2], Mark Neider[3], Arthur Kramer[4], Lester C. Loschky[1]; [1]Department of Psychological Sciences, Kansas State University, [2]Department of Psychology, Concordia University, [3]Department of Psychology, University of Central Florida, [4]Department of Psychology, University of Illinois at Urbana-Champaign

Previous work (Ringer et al., 2013, VSS) showed that blur detection in natural scenes was unaffected by cognitive load in a gaze-contingent blur detection task, suggesting that blur may be detected preattentively. However, cognitive load was manipulated by the N-back task with a maximum of 3-back, which may have been insufficient load to affect attention. That study used both auditory and visual n-back tasks (from single-task to dual-task with 0- to 3-back) in two experiments, while participants completed gaze-contingent blur detection. The current study analyzed the eye movement data from the previous study to directly measure the effects of cognitive load on overt attention. Specifically, cognitive load has been shown to reduce attentional breadth as measured by a tighter distribution of fixations within an image (Miura, 1986; Reimer et al., 2012). Furthermore, the previous study had used a simple new/old picture memory task to encourage eye-movements, thus we measured recognition memory as another proxy for the effects of cognitive load on attention. Specifically, the encoding of visual information into long-term memory has been shown to be affected by attentional selection (Cowan, 1993; Matsukura et al., 2011). Finding effects of the N-back task on attention as measured by both eye movements and visual recognition memory would rule out the argument that the N-back load was insufficient to affect visual attention. Results: Fixation distributions showed increased density at the center of the image for the 3-back dual task over single-task blur detection (i.e., a significantly smaller Bivariate Contour Ellipse). Furthermore, recognition memory accuracy was significantly impaired with increasing N-back. Together these results provide compelling evidence that the cognitive load manipulation would have been powerful enough to evoke an attentional effect on blur sensitivity if blur thresholds were amenable to attentional manipulations.

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33.536 Spatial attention across perception and action Moran Israel[1](morani.israel@gmail.com), Asher Cohen[1]; [1]Department of Psychology, The Hebrew University of Jerusalem

Converging evidence in cognitive neuroscience has generated the notion that perception and action may share the same spatial representation, on the neuronal level as well as the cognitive level. The Simon effect (Simon, 1969) demonstrates this complex relationship between perception and action. According to this phenomenon, spatial relation between perception and action (stimuli and response) can affect performance even when the spatial information of the stimulus is irrelevant to the task. In our study subjects performed two tasks, either separately (the single task condition) or simultaneously (the dual task condition). In the first, shape task, two colored shapes were presented bilaterally. The subject's task was to name one of the shapes according to its color and ignore the other shape. In the second, tone task, subjects were required to respond manually with either a left or right button according to the pitch of a tone. The input for both tasks appeared simultaneously, and subjects were instructed to respond to both tasks as fast as possible, without prioritizing either of them. We found a sizable dual task cost when the two tasks were performed simultaneously, particularly for the shape task. Moreover an orthogonal compatibility effect was found between the side of the relevant shape and the side of the correct response in the tone task, for both tasks- a between tasks Simon-like effect. These results demonstrate a clear overlap between representations of space in perception and action, and indicate that both perception and action use the same spatial representations in the brain, even when the spatial information comes from two distinct tasks.

33.537 Amelioration of the distracting effect of cellphone driving Whitney N. Street[1](street1@illinois.edu), John G. Gaspar[1,2], Matthew B. Windsor[1], Ronald Carbonari[2], Henry Kaczmarski[2], Arthur F. Kramer[1,2], Kyle E. Mathewson[2]; [1]Department of Psychology and Beckman Institute, University of Illinois at Urbana-Champaign, [2]Beckman Institute for Advanced Science and Technology, University of Illinois at Urbana-Champaign

Cellphone use is known to impair driving performance, yet persists. This impairment is thought to stem, in part, from the remote conversation partner's lack of situational awareness. In this study, pairs of participants completed a driving task in a high-fidelity driving simulator while naturally conversing. Similar to previous studies, drivers drove alone, with a passenger, and talking on a hands-free cellphone. Additionally, drivers completed the task while their conversation partner could see both the road ahead and the driver's face via a video feed (videophone). If the situational awareness theory is true, this additional video information should mitigate the negative effects of cellphone distraction. When another vehicle unexpectedly merged, collision rates were significantly higher in the cellphone condition than the videophone, passenger, or drive-alone conditions which were equivalent. No group differences were found in collision rates during lead-vehicle braking events. Additionally, both drivers and their conversation partners made shorter utterances when on the videophone. When referring to traffic, videophone drivers and partners took more turns talking and made longer, more frequent traffic references. Therefore, additional video seen only by the conversation partner changed the conversation dynamics and decreased the likelihood of a collision with an unexpected merging vehicle. Unlike in-car passengers who mostly looked at the road, videophone partners looked about equally at the driver's face and the road suggesting that out-of-car partners are attaining their situational awareness differently or possibly less optimally than in-car passengers. The remote conversation partner's additional video information allows them to help drivers by modulating the dynamics of the conversation and referring to traffic more often, cutting the likelihood of collisions in half. This finding has direct applications to distracted driving. Further research is needed to investigate if this benefit remains when the videophone conversation partner is distracted as occurs in the real world.

33.538 Electrophysiological evidence that acute bouts of exercise modulate multiple stages of information processing Tom Bullock[1,2](bullock@psych.ucsb.edu), Hubert Cecotti[1,2], Barry Giesbrecht[1,2]; [1]Department of Psychological and Brain Sciences, University of California, Santa Barbara, [2]Institute for Collaborative Biotechnologies, University of California, Santa Barbara

Acute bouts of physical exercise are known to modulate cognitive task performance (Lambourne & Tomporowski, 2010) and brain activity measured using electroencephalography (EEG; Bailey et al., 2008). However, EEG studies have largely focused on cortical oscillations in different frequency bands (alpha, beta; Brummer et al., 2011) and little is known about how acute bouts of exercise affect the temporal dynamics of information processing. To investigate this issue, we used the event-related potential (ERP) technique to measure fluctuations in the patterns of perceptual and cognitive processes measured during physical exercise. Nine participants viewed continuous rapid serial visual sequences (2Hz) of stimuli consisting of frequent non-targets (cars 80%), rare non-targets that did not require a response (faces oriented right, 10%), and rare targets (faces oriented left, 10%) that required a simple detection response. Each subject viewed the sequences under three conditions whilst sitting on a stationary bike: resting, pedaling at a low intensity (~40W power output, mean rating of perceived exertion (RPE) = 8.5), and pedaling at a higher intensity (~60% of VO2max, mean RPE = 14.1). In all conditions, EEG was recorded from 32 scalp electrodes. Analyses of the ERP data revealed that the mean amplitude of the parieto-occipital P1 component evoked by the frequent non-targets was larger during low intensity exercise compared to rest ($p<.05$). While the amplitude of the target evoked P3 component was not modulated by exercise, there was a marginal effect of exercise on peak latency, such that latency was reduced under high intensity exercise compared to rest ($p=.055$). This concurs with behavioral data which demonstrate significantly faster RTs under high intensity exercise compared to rest ($p<.05$). Together these results are consistent with the conclusion that exercise modulates multiple stages of information processing, ranging from post-perceptual target categorization to early stage sensory processing.

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33.539 Prism adaptation ameliorates pseudoneglect by enhancing target processing in right hemispace Elizabeth Nguyen[1](elizabeth.nguyen@sydney.edu.au), Patrick T. Goodbourn[1], Alex O. Holcombe[1]; [1]School of Psychology, The University of Sydney, Australia

Line bisection and related tasks reveal a leftward attentional bias in healthy individuals (pseudoneglect). This bias is reduced by adaptation to visual experience of the scene shifted to the left. One theory is that a balance of activation between the two cerebral hemispheres—usually favoring the right hemisphere—is shifted after prism adaptation. Hence, an increase in processing on one side should be accompanied by a decrease on the other. Standard methods, such as line bisection, yield only relative measures of left–right performance; thus to test the theory, we instead derived inde-

pendent, absolute measures of performance for left and right hemispace. Because it has been proposed that the two hemispheres are differentially involved in temporal processing, we also assessed whether adaptation affected temporal parameters of attentional selection. Goodbourn & Holcombe (VSS 2013) found a leftward bias, consistent with pseudoneglect, when two rapid serial visual presentation (RSVP) streams of letters were presented concurrently to the left and right of fixation. Target letters were cued simultaneously in both streams. While participants frequently reported simultaneous letters, efficacy of target selection was substantially higher for the left stream than for the right. In the present study, twelve observers completed the dual-RSVP task before and after adaptation to three types of prisms: left-shifting, right-shifting, and control. Consistent with previous pseudoneglect studies, no performance changes were found after right-shifting or control prism adaptation. In contrast, adaptation to left-shifting prisms reduced the leftward bias, selectively boosting right-stream performance: relevant letters were reported 9% more often after adaptation (P = 0.03). We found no accompanying decrement in left-stream performance. Temporal parameters (latency and precision) were unchanged for both sides. These findings suggest prism adaptation ameliorates biases not by rebalancing hemispheric activation, but rather by selectively enhancing processing of stimuli in the non-dominant right hemifield.

33.540 **Is the attentional boost effect really a boost?** Khena Swallow[1](kms424@cornell.edu), Yuhong Jiang[2]; [1]Department of Psychology, Cornell University, [2]Department of Psychology, University of Minnesota

When performing two tasks at once, increasing attention to one task typically impairs performance of the other. In contrast, the attentional boost effect suggests that dual-task facilitation can also sometimes occur: Memory for images that coincide with an unrelated stimulus that requires a response (target) is better than memory for images that coincide with a stimulus that requires no response (distractor). This performance advantage reflects a difference in memory for images presented with targets relative to those presented with distractors. As a result, it could reflect either an enhancement triggered by target detection or inhibitory processes triggered by distractor rejection. To determine whether the attentional boost effect is truly a boost, a baseline measure of image memory under dual-task encoding conditions is necessary. In several experiments participants memorized a series of continuously presented faces while monitoring a second series of unrelated squares. The face could appear in three different encoding conditions: on its own, with a square that required a response (target), or with a square that required no response (distractor). Processes associated with both target detection and distractor rejection were minimized when faces appeared on their own, making this condition suitable as a baseline measure of face encoding. Consistent with the claim that the attentional boost effect is triggered by target detection, the data showed that memory for faces coinciding with a target square was enhanced relative to faces in both the baseline and distractor conditions. There was no evidence of a difference in memory for faces in the baseline and distractor conditions. We conclude that detecting a behaviorally relevant event boosts memory for concurrently presented images in dual-task situations.

33.541 **Cognitive load modulates early visual perceptual processing** Virginia Liu[1](virpingliu@gmail.com), Jason Forte[1], Luca Cocchi[2], David Sewell[1], Olivia Carter[1]; [1]Melbourne School of Psychological Sciences, University of Melbourne, [2]Queensland Brain Institute, University of Queensland

In the current dual-task literature, it seems accepted that cognitive load does not affect early perceptual processing but this issue has not been systematically evaluated. Recent studies show that when observers held information in working memory, performance on an unrelated visual perceptual task (i.e., grouping-by-proximity) was improved (increased accuracy and reduced reaction time)(Cocchi et al, 2011). Thus, cognitive control mechanisms supporting working memory may modulate concurrent but independent visual perceptual processing. Four experiments were conducted to further explore the nature of cognitive load modulation on early visual processing. In experiment 1, a contrast detection task was employed to explore whether contrast sensitivity varies under different cognitive loads. Participants judged the orientation of a small Gabor of various contrasts located in parafovea. In experiment 2 to 4, three tasks that are thought to elicit surround-suppression i.e., a motion discrimination task (Tadin et al., 2003), the Chubb illusion and a contrast detection task under surround suppression in periphery (Petrov & Mackee, 2006) were employed to investigate whether cognitive load modulates surround suppression. In all experiments, the perceptual tasks were performed during a concurrent no-, low- and high-working memory load task. Results of experiment 1 show that under high cognitive load, there is a rightward shift of the psychometric function suggesting cognitive load influences early visual processing. No effects of cognitive load on surround inhibition were found in experiments 2 to 4. According to the contrast-normalization model, the balance between excitation and suppression determines contrast response. The results of this study suggest that under high cognitive load excitatory drive is diminished whereas surround suppression remains unchanged. Taken together, cognitive load effects do penetrate to the early visual perceptual processing stage, however, these effects appear limited to excitatory responses.

33.542 **Monitoring for visual prospective memory events reduces visual processing speed in ongoing tasks** Christian H. Poth[1](c.poth@uni-bielefeld.de), Claus Bundesen[2], Anders Petersen[2], Werner X. Schneider[1,3]; [1]Department of Psychology, Bielefeld University, Bielefeld, Germany, [2]Center for Visual Cognition, University of Copenhagen, Copenhagen, Denmark, [3]Center of Excellence Cognitive Interaction Technology, Bielefeld University, Bielefeld, Germany

In event-based prospective memory (EPM) tasks, the intention to act in response to an external event is formed, retained, and, when the event occurs, enacted. Monitoring of the environment for such an event might be necessary for triggering the memory-based response. This is thought to make attentional demands and thereby interfere with other ongoing tasks. These monitoring demands have never been specified for the visual domain. Here we asked whether the attentional components specified by Bundesen [1990, Psychological Review, 97(4), 523-547] are affected during environmental monitoring and whether this varies with the event's perceptual salience. The ongoing task followed Vangkilde, Bundesen, and Coull (2011, Psychopharmacology, 218, 667-680). Letters were shown for different durations and afterwards to be reported. The attentional components threshold of conscious perception, capacity of visual short-term memory, processing speed, top-down controlled selectivity, and laterality of attentional weighting were estimated from report-accuracy. Events for the EPM task were brief increases in the fixation cross's luminance on 10% of the trials (randomly chosen). Responses (button-press) to events were required in the event and salient-event conditions, but not in the control condition. Events were of higher brightness (salience) in the salient-event condition compared with the event and control conditions. Only trials without events or responses were analyzed, to capture only intention retention effects. Visual processing speed was lower in the event and salient-event condition than in the control condition. Likewise, it was lower in the event than in the salient-event condition. This was replicated in another experiment, while there were no stable effects on the other attentional components. In sum, visual processing speed for an ongoing task's stimuli is reduced during the retention interval of a visual EPM task. Further, this reduction seems to be less pronounced when EPM events are more salient and thus might require less active monitoring.

Attention: Individual differences

Sunday, May 18, 8:30 am - 12:30 pm
Poster Session, Pavilion

33.543 **Cortical magnification factor and population receptive field size in human V1 predict the bottom-up saliency map** Xilin Zhang[1](zhangxilin@pku.edu.cn), Fang Fang[1,2,3]; [1]Department of Psychology and Key Laboratory of Machine Perception (Ministry of Education), [2]Peking-Tsinghua Center for Life Sciences, [3]IDG/McGovern Institute for Brain Research Peking University, Beijing 100871, P.R. China

In this study, we explored the relationship between the bottom-up saliency map and functional properties of human V1. For twenty-six subjects, we first performed a psychophysical experiment to measure their bottom-up saliency map with the method developed by Zhang and colleague (Neuron, 2012). The method used the Posner cueing paradigm to measure the attentional attraction (i.e. the saliency strength) of a foreground region in the stimulus that was backward masked and was invisible to subjects. Then, we performed fMRI experiments to estimate cortical magnification factors (CMF) and population receptive fields (pRF) in the subjects' visual cortical areas responding to the foreground region with the method proposed by Dumoulin and Wandell (NeuroImage, 2008). Along the visual hierarchy (V1, V2, V3, V4 and IPS), the CMF decreased and the pRF size increased. Significantly, across individual subjects, the saliency strength of the foreground region positively correlated with the V1 CMF, but negatively with the V1 pRF size. No significant correlation was found in other cortical areas. We speculate that the higher saliency may result from reduced lateral interactions between V1 neurons due to smaller pRFs and larger CMFs, and the intrinsic properties of V1 may provide critical constrains for generating the bottom-up saliency map.

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33.544 **Difference between eyes-closed and eyes-open resting state alpha power is an indicator of susceptibility to the rubber hand illusion** Su-Ling Yeh[1,2,3](suling@ntu.edu.tw), Timothy Lane[4,5,6], Jifan Zhou[1], Ting-yi Lin[1,4], Chia-Hsin Kuo[1,4], Cheng-Yun Teng[1,4]; [1]Department of Psychology, National Taiwan University, Taipei, Taiwan, [2]Graduate Institute of Brain and Mind Sciences, National Taiwan University, Taipei, Taiwan, [3]Neurobiology and Cognitive Neuroscience Center, National Taiwan University, Taipei, Taiwan, [4]Graduate Institute of Medical Humanities, Taipei Medical University, Taipei, Taiwan, [5]Institute of European and American Studies, Academia Sinica, Taipei, Taiwan, [6]Research Center for Mind, Brain, and Learning, National Chengchi University, Taipei, Taiwan

In undergoing the rubber hand illusion (RHI) participants experience an imitation hand as belonging to self, when viewing that hand as it is stroked synchronously with the occluded real hand. Although the illusion can be robust, not everyone experiences it. Approximately 30% of participants do not. To explore the difference between the 70% who are susceptible (RHI-S) and the 30% who are not (RHI-N), our study examined resting-state alpha power variance. RHI-S and RHI-N participants were selected by a pre-test in which RHI onset time was recorded during the induction period. RHI-S was operationally defined as participants for whom the illusion occurred within 30s after induction began; RHI-N, as participants for whom the illusion did not occur within three minutes. Resting-state EEG in eyes-closed (EC) and eyes-open (EO) conditions were recorded at the start of the formal experiment. Next the RHI induction procedure was repeated to examine RHI stability. Finally, the baseline was measured again. When comparing pre-test to formal test results, participant susceptibility was unchanged, suggesting RHI susceptibility is stable. Frequency analysis showed that alpha power variance between EC and EO was significantly larger for RHI-S participants than for RHI-N participants, a pattern that remains unchanged after completion of the RHI induction attempt. Ever since discovery of the Berger Effect—decrease or disappearance of alpha band oscillations when eyes open—the role of alpha in mental activity has been subject to debate. Our findings are consistent with interpretations that suggest alpha is associated with self-relatedness and inhibition of attention to the external world. It might be that RHI-N participants attend somewhat less to external stimuli, while attending to personal concerns, even after their eyes open, causing them to rely more on internal (e.g., proprioceptive) rather than the external (e.g., visual) information when generating a sense of limb ownership.

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33.545 **Intact functioning of exogenous spatial attention in amblyopic adults** Marisa Carrasco[1](marisa.carrasco@nyu.edu), Mariel Roberts[1], Rachel Cymerman[2], R. Theodore Smith[2], Lynne Kiorpes[1,2]; [1]Department of Psychology, Center for Neural Science, New York University, [2]Department of Ophthalmology, Langone Medical Center, New York University

Goal. Amblyopia—a developmental disorder characterized by a deficit in visual acuity, contrast sensitivity and position acuity in one eye following abnormal binocular experience during childhood—is the leading cause of monocular impairment from children to middle-aged adults in the US. Exogenous attention increases contrast sensitivity as assessed by orientation discrimination tasks in adults with normal vision. We explored whether exogenous attention similarly improves contrast sensitivity in amblyopes, is intact whether viewing with the amblyopic or fellow eye, and whether it differentially affects processing at locations across the visual field. Methods. 15 amblyopic (9-strabismic, 6-anisometropic) and 15 control (age- and gender-matched) adults were tested monocularly on a 2-AFC-orientation discrimination task. Four Gabor patches (independently and randomly tilted ±20° from vertical) appeared along the vertical and horizontal meridians. To manipulate attention, participants were presented with either one (valid-cue) or four (neutral-cue) peripheral pre-cues. Participants reported the orientation of the Gabor indicated by a postcue. In the valid-cue condition, the precue and postcue locations matched. Task difficulty was equated between eyes and across observers by adjusting stimulus contrast in the neutral-cue condition. Results. Performance was significantly higher and faster for the valid- than the neutral-cue condition for both groups. There were no 3-way or 2-way interactions among group, attention condition, and eye: The magnitude of the attentional benefit did not differ between the two groups or the two eyes in each group. Moreover, both groups exhibited canonical performance fields–better performance along the horizontal than vertical meridian and at the lower than upper vertical meridian–and similar effects of attention at all locations. Conclusions. The performance benefit of exogenous attention was the same for both eyes of the amblyopic adults at all locations, demonstrating no difference from controls. Although amblyopic eyes process lower-quality visual information, exogenous attention remains functionally intact in amblyopic adults.

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33.546 **Dissociable Changes in Sustained Visual Attention Across the Lifespan** Bay McCulloch[1](baymcculloch@gmail.com), Michael Esterman[1,4], Laura Germine[3], Jeremy Wilmer[2], Joseph DeGutis[1]; [1]VA Boston Healthcare System, BAL LAB, [2]Department of Psychology, Wellesley College, [3]Psychiatric & Neurodevelopmental Genetics Unit, Massachusetts General Hospital, [4]Department of Psychiatry, Boston University School of Medicine

One fundamental aspect of attention is that it fluctuates from moment-to-moment, which manifests in performance variability. Increased variability in performance has been related to compromised functioning across many populations such as older adults and those with ADHD. Though previous studies have directly compared attentional fluctuations between groups of older and younger adults, they utilized small samples (N<100) and the nuanced details of this developmental process have yet to be fully characterized. To address this, we administered the gradual onset continuous performance task (gradCPT), a sensitive sustained attention task, to a very large web-based sample (N>4,000, testmybrain.org). The gradCPT requires participants to respond to the majority of stimuli (cities-90%) and withhold to rare target images (mountains-10%). The images gradually transition from one to the next every 800ms, which eliminates the exogenous effects of abrupt stimulus onsets and makes the task more reliant on intrinsic sustained attention abilities. The results demonstrate a highly significant positive relationship between age and reaction time variability that was best described by a quadratic function (adjusted R2=.20). Specifically, variability increased more rapidly with increased age. This age/reaction time variability relationship was significant after controlling for age-related changes in overall reaction time, response criterion, and accuracy, suggesting that it may be a unique aspect of aging. We also found substantial linear relationships between age and post-error slowing (R2=.17) as well as between age and caution towards erroneously pressing to mountain scenes (criterion C, R2=.10). Overall these results suggest two dissociable aging processes: a strategic, linear shift towards caution and reactivity to errors and a nonlinear increase in attentional fluctuations.

33.547 **Is High Contrast Viewing Condition Always Better? Not for The Useful Field of View Tests** John Paul Plummer[1](jpplummer@wichita.edu), Rui Ni[1]; [1]Department of Psychology, Wichita State University

Previous research has found that both the useful field of view (UFOV) and contrast sensitivity (CS) are effective predictors for accident risks, especially for aged drivers. It has been shown that with increased age observers exhibit slower processing of visual information in the central and peripheral visual field, especially when dividing their attention to two simultaneous tasks in different locations in the visual field, and less tolerance when perceiving objects under low contrast conditions. The current study aimed to investigate the effect of contrast on UFOV among younger adults. 18 participants (age M = 21.8, SD = 3.8) were first tested on their contrast threshold, using a contrast detection task (CD) with their dominant eye. They then went through a modified version of UFOV tests developed by Richards, Bennett, and Sekuler (2006) under three different contrast levels, with the highest Michelson contrast level set to 0.3, the low level set at CD threshold level, and the medium level set as the logarithmic midpoint between low and high contrast levels. In the UFOV tests we measured focused attention, focused-peripheral attention, and divided attention in three subtests, at five eccentricities (4, 8, 12, 15, and 20 deg) on display duration threshold using the BEST-PEST algorithm. The contrast was kept constant within a block of subtest. All variables were run as within-subjects variables and the order of contrast blocks were counterbalanced across participants. Significant main effects and interactions were found for all independent variables in all three subtests. In the focused attention task, performance deteriorated with decreased contrast, which was predicted. Surprisingly, in both the focused-peripheral task and divided attention task, the medium contrast level resulted in the lowest threshold in display duration, indicating a non-monotonic effect of contrast on the UFOV test.

33.548 **Establishing the Attention-Deficit Trait** Sophie Forster[1](s.forster@sussex.ac.uk), Nilli Lavie[2]; [1]School of Psychology, University of Sussex, UK, [2]Institute of Cognitive Neuroscience and Research Department of Cognitive, Perceptual and Brain Sciences, University College London, UK

Some people appear more prone to experiences of inattention and distraction than others. So far these individual differences have typically been measured using questionnaires (e.g. Broadbent et al., 1982). Here we sought to establish an attention deficit trait using task-performance distraction measures and assessing the extent to which individual differences in distractor interference correlate with attention deficit symptoms. Across two experiments, 151 participants performed a visual search task in the presence of either response competition flankers or entirely irrelevant distractor images of famous cartoon characters. The results of both experiments showed that attention deficit scores significantly predicted the level of reaction time interference from entirely irrelevant distractors. In contrast, these were unrelated to interference from similarly salient response-competition distractors. These findings are consistent with a recent report that clinical levels of ADHD are associated with irrelevant distraction, while often not associated with response competition effects, and establish this dissociation in the healthy non-clinical population. We conclude that an attention-deficit trait involves increased vulnerability to irrelevant distraction. The trait can be predicted from behavioural measures, but only if salient and entirely task-unrelated distractors are presented.

33.549 **Superior Visual Search Efficiency in High Trait Anxiety** Nick Berggren[1](nbergg01@mail.bbk.ac.uk), Thomas Blonievsky[1], Nazanin Derakshan[1,2]; [1]Department of Psychological Sciences, Birkbeck University of London, UK, [2]St John's College Research Centre, St John's College, University of Oxford, UK

Numerous studies have highlighted associations between self-report trait anxiety levels and impaired cognitive control (see e.g. Eysenck, Derakshan, Santos & Calvo, 2007). However, recent work has begun to also note associations between anxiety and visual perception, such as improved visual awareness for stimuli in high anxious individuals (Berggren, Blonievsky, & Derakshan, under review), as well as heightened ERP response on early visual components (e.g. Weymar, Keil, & Hamm, 2013). Notably, these effects occur not only for emotional stimuli but also affectively-neutral information. To test this account, we employed a feature versus conjunctive search task requiring participants to search through an array of letters for a target item, where efficient conjunctive search is known to require perceptual/attentional resources (Treisman & Gelade, 1980). Participants were pre-screened for high versus low levels of trait anxiety. As the set size of visual displays increased, we replicated the classic finding that featural search was relatively unaffected by increasing search difficulty, whereas conjunctive search was highly susceptible to the manipulation. Crucially, the high anxious group showed shallower increases in reaction times as set size increased for conjunctive search. This result suggests that high levels of anxiety are associated with superior visual search efficiency, implying that anxiety may influence perceptual processes as well as cognitive ones. We link this result to evidence of the amygdala enhancing perception through feedback connections with visual cortex (Amaral, Behniea, & Kelly, 2003); a network that may be bolstered by sustained experience of anxious mood.

Acknowledgement: Economic and Social Research Council 1+3 PhD Studentship

33.550 **Does attention to low spatial frequencies enhance face recognition? An individual differences approach** Blaire Dube[1](b-dube@uoguelph.ca), Karen Arnell[2], Catherine Mondloch[2]; [1]University of Guelph, [2]Brock University

Faces are widely regarded as "special" due to our reliance on holistic or configural processing for their successful recognition. The processing of low spatial frequency information has been associated with holistic processing and is thought to promote a face-specific recognition advantage. There are reliable individual differences in face recognition ability, and these are related to individual differences in various holistic processing measures. There are also stable individual differences in the tendency to use high or low spatial frequency information. To date, however, there have been no investigations of potential relationships between individual differences in high/low spatial frequency use and performance on face recognition tasks. The current study investigated whether individual differences in low spatial frequency use are related to individual differences in face recognition, as well as the extent to which these relationships are face-specific. Participants completed three different face recognition tasks, two non-face recognition control tasks, and a task pitting high and low spatial frequency information against each other. As predicted, individuals who showed greater reliance on low-spatial frequency information had better face recognition ability. However, increased use of low-spatial frequency information also predicted better recognition of non-face stimuli (i.e. cars and abstract art), and the relationship between face recognition and low spatial frequency use was not significant after statistically controlling for non-face recognition performance. The results suggest that the use of low-spatial frequencies in visual processing is beneficial to recognition in general, as opposed to garnering advantages that are specific to faces.

33.551 **The attentional blink in right parietal patients: Analysis of temporal selection parameters** Lorella Battelli[1,2](lbattell@bidmc.harvard.edu), Sara Agosta[1], Paolo Martini[3], Alex O. Holcombe[4], Patrick T. Goodbourn[4]; [1]Center for Neuroscience and Cognitive Systems@UniTn, Istituto Italiano di Tecnologia, Rovereto, Italy, [2]Berenson-Allen Center for Noninvasive Brain Stimulation and Department of Neurology, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, Massachusetts, USA, [3]Department of Psychology University of Warwick, Coventry, UK, [4]School of Psychology, University of Sydney, Australia

Patients affected by right parietal lesions have impairments in visual timing tasks (Battelli et al. 2008) and may also show an extended attentional blink (AB, Husain et al. 1997), an impairment in detecting the second of two targets appearing in close temporal succession. This overall disturbance of temporal attention may have distinct components that are differentially altered in patients. We used a rapid serial visual presentation (RSVP) display containing a stream of 26 letters presented at 8.6 items/sec. Two letters were targets cued by an annulus, and the number of items (the lag) between the first target (T1) and second target (T2) was varied. Participants were asked to report both targets. For each participant we measured accuracy for T1, and for T2 contingent on correct report of T1. By analyzing the serial position of non-target items reported as targets, we also derived estimates for three distinct components of attentional selection: (i) efficacy, comparable to the probability of reporting an item in a time window around the target; (ii) latency; and (iii) temporal precision. We tested three right parietal patients (FC, RR and PP). All showed an extended AB—in terms of both contingent T2 accuracy (i.e. exactly correct) and T2 efficacy (approximately correct)—replicating previous findings. FC and PP showed low T1 accuracy but normal T1 efficacy; in contrast, RR showed both low accuracy and low efficacy. For PP and RR, T1 and T2 selections were systematically delayed and less temporally precise relative to controls, whereas latency and precision were relatively spared for FC. Interestingly, patient PP showed lag-1 sparing, which was not evident for FC nor for RR. These results confirm that parietal patients show an extended blink, but point to substantial individual differences in component attentional processes. We discuss how these differences may relate to lesion site.

33.552 **Alerting cues affect the subitizing process: Evidence from developmental and acquired dyscalculia** Yarden Gliksman[1](yarden.gliksman@gmail.com), Avishai Henik[2]; [1]Department of Psychology, Ben-Gurion University of the Negev, [2]Department of Psychology, Ben-Gurion University of the Negev

Enumeration of elements (e.g., dots) differs as a function of their range. Subitizing (1-4 dots) is considered to be an accurate and quick process with reaction times (RTs) minimally affected by the number of presented elements. In contrast, in counting (5-9 dots) RT rises additively as a function of the number of dots presented. Observations from previous studies led us to investigate whether subitizing is a global process: (a) the right-TPJ (temporo-parietal-junction) is related to both global processing and alertness (Lamb et al., 1990); (b) alertness enhanced global processing (Weinbach & Henik, 2011); (c) the right-TPJ was found to be activated in the subitizing range and inhibited in the estimation range (Ansari et al., 2007). Moreover, recently we demonstrated that alerting modulated RT only in the subitizing range (Gliksman & Henik, in preparation). In the current study, we explored effects of range (subitizing vs. counting) and alertness in participant with acquired dyscalculia (AD) due to left intraparietal sulcus damage, and in participants with developmental dyscalculia (DD). AD and DD are characterized as having mathematics difficulty. Our results indicated that in the subitizing range, an alerting cue prior to a target created faster RT for AD (the same as for controls) and expanded the subitizing range of DD participants (4 vs. 3). In counting range, AD participant presented an opposite alerting effect (i.e., trials with an alerting cue were processed slower) and DD participants presented a small or null effect for the alerting cue. Since the right and left hemispheres involve global and local processing, respectively, the pattern of results of AD are in line with our suggestion that subitizing is a global process while counting is a local process. For the DD participants, their smaller-than-normal subitizing range can be explained by low efficiency of global processing, which might improve with alerting.

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33.553 **Flanking Magnitudes: Dissociation between Numerosity and Numerical Value in a Selective Attention Task**
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The current research examined whether attention and task relevance modulate numerical processing. In two experiments, participants were presented with a target matrix flanked by a distractor matrix and were asked to perform a comparative judgment (i.e., decide whether the target was larger or smaller than the reference 5). In Experiment 1, the target was symbolic (i.e., a single digit) and in Experiment 2, it was nonsymbolic (i.e., a random presentation of dots). In both experiments flanker matrices had two dimensions—numerosity and numerical value—which were manipulated orthogonally to create stimulus congruent, and stimulus incongruent conditions. Incongruent trials differed in the laterality between target and flanker (i.e., their location in relation to the reference 5). When responding to symbolic targets (Experiment 1), only the flanker's numerical value affected reaction times (RTs), whereas when responding to nonsymbolic targets (Experiment 2), only the flanker's numerosity affected RTs. In addition, the pattern of flanker interference differed between targets: for symbolic targets, laterality did not affect responses whereas for nonsymbolic targets, laterality did affect responses. These results imply both symbolic and nonsymbolic magnitudes can be automatically activated; however, this activation is contingent upon their relevance to the task at hand. Implications of these results on the efficiency of the visual processing system and on numerical cognition are further discussed.

33.554 **Individual differences in visual working memory capacity and search efficiency may predict distinct strategic processes for dot arrays by numerosity comparison sensitivity**
Giyeon Kim[1](giyeonkim90@gmail.com), Soohyun Cho[1], Joo-Seok Hyun[1]; [1]Department of Psychology, Chung-Ang University

Numerosity comparison, the ability to compare quantities of two arrays of elements, is assumed to be as important to human mathematical ability as attention and working memory presumably are important. Accordingly, we attempted to explore the relationship of an individual's sensitivity to numerosity differences with their visual working memory (VWM) capacity and visual search efficiency. First, we measured the participant's VWM capacity using a color-change detection task (i.e., Cowan's K), and their search efficiencies (i.e., search slope). We then measured their numerosity comparison sensitivities in several tasks, that required comparing the quantities of two sequential (200ms each) or bilateral arrays (200ms). The dots were places either at identical locations (i.e., fixed-position) or random (i.e., scrambled-position) across the arrays, while the ratio for their quantities varied across trials. Each participant's comparison sensitivity(termed alpha [α]) for numerosity was defined as a 75%-accuracy threshold on a modeled logistic function. This function demonstrated a sigmoidal pattern of accuracies along the incremental quantity difference between the arrays, such that a lower alpha indicated higher sensitivity. The analyses for the sequential array trials found a negative correlation between Cowan's Ks and alphas in the fixed-position condition, and a positive correlation between search slopes and alphas in the scrambled-position condition. These results indicated that the participants used a strategy to exploit VWM capacity only if they were able to store the array as a global image, while they used a strategy to exploit a rapid shift of attention if they were unable to. However the analyses for the bilateral array trials found no correlations, indicating neither the strategy was possible due to the doubled array size and the brief exposure duration. These suggest that an individual's numerosity comparison sensitivity can be predicted by his or her VWM capacity and search efficiency.
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33.555 **Individual differences in affect and personality predict attentional and conceptual breadth**
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Several studies have investigated the effect of induced mood state on attentional and cognitive breadth. Early studies concluded that inducing a positive mood state broadened attention and cognition, while inducing a negative mood state narrowed these. However, recent reports have suggested that when valence and motivational intensity are unconfounded, low motivational intensity promotes cognitive breadth, whereas high motivational intensity promotes cognitive narrowing. Here we examine whether self-reported dispositional affect (using the circumplex affect questionnaire) and approach/avoidance tendency (using the BIS/BAS Scale) can predict attentional breadth (using the global-local Navon letter task) and conceptual breadth (using the Remote Associates Test - RAT), with no mood manipulations or cues. Results showed that low arousal affect was positively associated with both measures of cognitive breadth. In contrast, approach motivation (BAS-Drive) was positively associated with a narrow attentional focus on the global-local task. Neither pleasant nor unpleasant valence (nor their difference) predicted any measure of cognitive breadth or focus. Overall, the results suggest the importance of arousal, motivational intensity and approach, as predictors of breadth of cognition. Finding that dispositional measures can also predict breadth of cognition suggests that affect and personality may underlie previously observed trait-like consistency in global-local bias.
Acknowledgement: NSERC

33.556 **Individual Differences in Media Multitasking and Inattentional Blindness**
D. Alexander Varakin[1](donald.varakin@eku.edu), Brian Huybers[1]; [1]Department of Psychology, College of Arts and Sciences, Eastern Kentucky University

Previous research on media multitasking suggests that individuals who regularly multitask are more susceptible to interference from task irrelevant stimuli than individuals who rarely multitask (Ophir, Nass, & Wagner, 2009, PNAS). This finding is consistent with the idea that frequent multitaskers are more likely to notice task-irrelevant stimuli than infrequent multitaskers. However, past research did not measure awareness of the task-irrelevant stimuli. The present study investigated the relationship between media multitasking and inattentional blindness (IB), which occurs when individuals fail to notice task-irrelevant, unexpected stimuli while performing an attentionally demanding cover task. As in past research, the Media Multitasking Index (MMI; Ophir, Nass, & Wagner, 2009) was used to classify participants (n = 95) as high media multitaskers (more than 1 SD above the sample's mean MMI score, n = 14) or low media multitaskers (less than 1 SD below the sample's mean MMI score, n = 12). In addition, participants in the middle of the MMI distribution were placed into middle-low (between -1 and 0 SDs from mean, n = 41) and middle-high (between 0 and 1 SDs from mean, n = 28) groups. Mack and Rock's (1998) paradigm was used to measure IB. Participants completed four cover task trials that involved making judgments about a cross that was briefly presented in the periphery. On the fifth trial, an unexpected stimulus was presented at fixation at the same time as the cross, and detection of this stimulus was used as a measure of IB. Detection rates were 57% for the high group, 43% for the middle-high group, 41% for the middle-low group, and 50% for the low group. There was no statistical association between MMI group and detection, $p > .05$. These results suggest that self-reported media multitasking is not strongly related to inattentional blindness.

33.557 **Top down effects in the real-world: An empirical assessment of smoker status on visual attention to brand and warnings when viewing different tobacco package designs**
Tim Holmes[1,2](tim@acuity-intelligence.com), Alice Lowenhoff[1,2], Jon Ward[1], Hayley Thair[3], Elina Nikolaidou[1]; [1]Acuity Intelligence Ltd, [2]Royal Holloway, University of London, [3]University of Nottingham

Recent studies reporting an increase in the attention to health warning messages when highly salient branding is removed from cigarette packages suggest that tobacco users might provide a ready source of participants to study the real-world top-down modulation of attention. We recruited a gender balanced sample of 120 participants (18-73 years, mean 38, stdev 16), comprising 40 non-smokers, infrequent smokers and regular smokers. Life size, photographic images of physical packages were presented for 10 seconds each on high definition screens whilst eye-movements were recorded using a Tobii TX300. A 2x2 design (branded vs. plain, text warning vs. graphic) was used for 8 top UK brands with current UK text and graphic warning messages. 8 unfamiliar "fake" tobacco brands were also included, as well as an equal number of distractor stimuli showing real and fake food and drink products, meaning each participant saw 128 images in total, presented in random sequence over 4 blocks. Our results suggest that infrequent smokers behave differently from regular and non-smokers and show a slower disengagement from the warning messages. Moreover, regular and non-smokers are strongly resistant to salience effects, with attention to the brand dominating even with the proposed plain packaging.
Acknowledgement: Phillip Morris International

Sunday AM

Face perception: Identity

Sunday, May 18, 8:30 am - 12:30 pm
Poster Session, Pavilion

33.558 Different Spatial Frequency Tuning for Judgments of Eye Gaze and Facial Identity

Mark Vida[1](vidamd@mcmaster.ca), Daphne Maurer[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University

Humans use the direction of people's gaze as a cue to their mental and emotional states. Human adults are most efficient in using low (coarse details) to mid (finer details) spatial frequencies to discriminate facial identities (Gao & Maurer, 2011). Adults are highly sensitive to changes in the direction of gaze (Vida & Maurer, 2012a). Here we tested whether adults' sensitivity to eye gaze, like their sensitivity to identity, is tuned to a limited range of spatial frequencies. In Experiment 1, participants (n=4) viewed faces presented with filtered noise that masked one of 10 narrow spatial frequency bands, with the centre frequency of the noise varying between blocks. Participants discriminated between two male faces or two female faces, or between gaze shifted to the left or right by 4.8º or 8º. We measured participants' contrast thresholds for each task, and used an ideal observer analysis to evaluate the importance of each frequency band for human sensitivity, taking into account the amount of information available to perform the task. For judgments of identity, participants relied on low to mid frequencies, but not on higher frequencies, a pattern consistent with previous studies (Gao & Maurer, 2011). For eye gaze, a small range of mid to high frequencies was most important, and the highest frequency important for gaze was higher than that for identity. In Experiment 2, participants (n=6) discriminated among horizontal and among vertical shifts of gaze. The most important frequencies were the same as for judgments of gaze in Experiment 1. However, the surrounding frequencies were less important for horizontal than vertical judgments, a result that may reflect finer tuning for horizontal judgments. Together, these results provide the first evidence that sensitivity to gaze is tuned to higher spatial frequencies than sensitivity to facial identity.

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33.559 Enhancing facial identity perception using high frequency transcranial random noise stimulation

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Recently, a number of studies have begun to highlight the potential of transcranial electrical stimulation as a tool to facilitate a variety of cognitive and perceptual abilities. Despite this, few studies have examined the utility of this approach for the processing of social cues. Here, we conducted two experiments to explore whether a single session of high frequency transcranial random noise stimulation (tRNS) targeted at posterior temporal cortices would enhance facial identity perception. In experiment 1, participants received twenty minutes of active high frequency tRNS or sham stimulation prior to completing tasks examining facial identity perception (Cambridge Face Perception Test) or trustworthiness perception. In the Cambridge Face Perception Test, participants were required to sort pictures of faces according to the degree of similarity between a target face and six images that were morphed between the target face and another person. In the trustworthiness task, participants were shown six faces that varied in their ratings of perceived trustworthiness; the participants' task was to sort the faces from most to least trustworthy. Active tRNS facilitated facial identity perception, but not trustworthiness perception. In experiment 2, participants received twenty minutes of active high frequency tRNS targeted at posterior temporal cortices or motor cortices prior to completing the Cambridge Face Perception Test. TRNS targeted at posterior temporal cortices enhanced performance relative to motor cortex stimulation. These findings show task and site specific enhancements in facial identity perception following high frequency tRNS targeted at posterior temporal brain areas.

Acknowledgement: Economic and Social Research Council

33.560 Adaptation to Dynamic Faces Produces Face Identity Aftereffects

Linda Jeffery[1,2](linda.jeffery@uwa.edu.au), Samantha Petrovski[1,2], Gillian Rhodes[1,2]; [1]The ARC Centre of Excellence in Cognition and its Disorders, [2]School of Psychology, The University of Western Australia

Face aftereffects have been used extensively as a tool for understanding the neural mechanisms underlying face recognition. It has also been argued that adaptive coding, as demonstrated by face aftereffects, plays a functional role in face recognition by calibrating our face norms to reflect current experience. Face aftereffects are well established for static stimuli, but have only recently been shown for dynamic faces. If aftereffects tap high-level mechanisms that are critically involved in everyday face recognition then they should occur for moving faces. Here we ask whether the face identity aftereffect can be induced using dynamic adaptors. This aftereffect occurs when adaptation to a particular identity (e.g. Dan) biases subsequent perception toward the opposite identity (e.g. antiDan). We adapted participants to real faces that displayed either rigid (head movement), non-rigid (facial muscle movement) and no motion (static image) and tested for aftereffects in static antifaces. Adapt and test stimuli differed in size, to minimize low-level adaptation. Aftereffects were found in all conditions, suggesting that face identity aftereffects tap high-level mechanisms important for face recognition. Aftereffects were not significantly reduced in the motion conditions relative to the static condition. Indeed, the non-rigid adaptors produced significantly larger aftereffects than did the rigid or static adaptors, possibly because the social motion they displayed (speaking and smiling) elicited greater attention.

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33.561 Determinants of ensemble representations for face identity

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A face conveys an abundance of information about a person, such as his or her gender, current emotional state, and identity. Such information can be efficiently extracted in a glance, and apparently without much effort, when viewing a single face. However, humans are often confronted with multiple faces at once. In this situation, ensemble representations can be derived from groups of faces via a cognitive mechanism that promotes extraction of average information from the group, often at the expense of accurate information about individual faces. There is some evidence that such ensemble representations can even be generated for facial identity. In two experiments, we tested the assumption that ensemble representation could serve as a quick and efficient way to extract identity information from groups of faces. We systematically varied two parameters that affected the extent to which participants were able to encode the identity from individual faces presented as a group: presentation duration and number identities presented. After viewing ensembles of different identities, probe faces were judged according to whether or not they had been presented. We found that ensemble representations, as measured by incorrect "present" responses given to morphed averages of a face group, were closely linked to memory for individual faces. There was little evidence for ensemble representations being coded either at short presentation durations or when groups comprised many different identities, suggesting that observers do not encode the mean identity of any group of faces at a glance. Instead, ensemble representations for facial identity were found only when representations for individual faces were also prominent. This finding suggests that ensemble representations might be formed during a later stage of face processing, which requires accurate individual representations of each face in a group.

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33.562 Modifying a face to make it more memorable or forgettable

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Upon a single glance at a new face, we are wired to automatically tag the person with physical, personality, social and emotional attributes. Importantly, some novel faces leave a lasting impression that persists in your memory. Knowing that face memorability -the degree to which a face photograph is remembered or forgotten - is an intrinsic attribute of the image, consistent across different observers (Bainbridge, JEP:G 2013), here we present and test a shape-deforming face model that subtly modifies natural photos of faces towards enhancing or reducing their memorability

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(Khosla, ICCV 2013). After learning from local landmarks and computer vision features, the model is able to automatically predict the memorability score of a novel face. Then, given a specific photo, the model can synthesize novel versions of an individual's photo along a memorability axis, while keeping other attributes (gender, age, emotion, attractiveness and identity) constant. In two crowd-sourcing visual memory experiments run with separate sets of people, observers are shown a sequence of individual images, for a second each, which have been manipulated along the axis of memorability, unbeknownst to them. Each experiment contains one version of a face, made either more or less memorable. Some faces are repeated after a few minutes in the sequence and observers are asked to press a key whenever they recognize a face they saw before. Memory performances show that the more memorable faces are recognized more often than the less memorable ones in 75% of the cases (p<0.0001). This difference is found along the whole spectrum of memorability scores. Our findings demonstrate that memorability is a facial trait that can be manipulated like age or emotion, changing the whole face in subtle ways to make it look more distinctive and memorable, or more typical and forgettable. Additional details at http://facemem.csail.mit.edu.

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33.563 **The time course of horizontal tuning during face identification** Matthew V. Pachai[1](pachaim@mcmaster.ca), Allison B. Sekuler[1], Patrick J. Bennett[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University

It is now well established that face identification is supported specifically by information contained in the horizontal orientation band (Dakin and Watt, J Vis 2009), and we have shown that observers who selectively utilize this information demonstrate greater overall identification performance (Pachai et al, Front Psychol, 2013). Still unknown, however, is the extent to which the horizontal tuning supporting identification is deployed throughout stimulus exposure. To this end, we examined the rapid processing of identity information by dynamically masking the orientation content of a face in a 10AFC identification paradigm. In five 53ms intervals of a 265ms stimulus presentation, we generated independent white noise masks for which we randomly modulated the power contained in the horizontal and vertical bands. Logistic regression models assessed the effect of noise orientation power and time interval on identification accuracy for each observer. These models fit the data well, so we conducted an analysis of individual regression coefficients as a function of time and orientation. This analysis revealed significant effects of time, demonstrating the greater influence of information collected earlier in presentation, and orientation, demonstrating the greater influence of horizontal structure relative to vertical. On average, the effect of orientation was significant in all time windows except the first (i.e., 0-53ms), which suggests that horizontal tuning evolves through stimulus exposure. However, some individual observers exhibited horizontal tuning even in the earliest time window, highlighting the importance of individual differences. We currently are examining the relationship between the temporal evolution of orientation tuning effects and individual differences in speeded identification accuracy. Together, these results further demonstrate the importance of horizontal structure for accurate face identification and suggest that diagnostic orientation structure for face perception is extracted within the first 100ms of stimulus presentation.

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33.564 **Repetition adaptation for individual human faces in 9-month-old infants? – An ERP study** Stefanie Peykarjou[1,2](stefanie.peykarjou@psychologie.uni-heidelberg.de), Sabina Pauen[2], Stefanie Hoehl[2]; [1]Face Categorization Lab, Institute for research in psychological sciences, Université Catholique de Louvain, [2]Developmental and Biological Psychology, Psychological Institute, Heidelberg University

Infants can recognize their caregivers and unfamiliar faces (Bushnell, 2001), but little is known regarding neural correlates of the representation of individual unfamiliar faces. In adults, repetition adaptation effects have been observed for the N170 (Caharel, et al., 2009) and the N250 (Schweinberger, et al., 2004). The current study examined 9-month-olds' representation of individual faces by looking at ERP repetition adaptation for repeated vs. unrepeated faces. N = 18 infants (9 months 2 days – 9 months 28 days) were presented with face targets that were either (1) unprimed (i. e., preceded by a house), (2) preceded by another face, or (3) preceded by the same face. Faces that were primed by a face (repeated or unrepeated) elicited smaller P1 amplitude (M = -3.99 µV, SD = 6.7) than unprimed faces (P1 amplitude: M = -1.65 µV, SD = 6.0), F(1,17) = 6.268, p <.05. P1 latency was reduced for primed (M = 107.68 ms, SD = 7.6) compared with unprimed faces (M = 111.17 ms, SD = 5.7), F(1,17) = 5.948, p <.05, indicating facilitated processing of primed faces. Moreover, repetition effects were observed for repeated compared to unrepeated faces at the level of a double-peaked negative component (150-300ms). Latency of the first peak ("N170") tended to be reduced for unrepeated faces (repeated: M = 156.13 ms, SD = 24.1, unrepeated: M = 148.76 ms, SD = 19.4), F(1,17) = 3.410, p = .082. Latency of the second peak ("N290") was reduced for repeated faces (repeated: M = 228.25 ms, SD = 28.9, unrepeated: M = 240.13 ms, SD = 34.5), F(1,17) = 4.673, p <.05. In line with previous research, this suggests that the N290 is a neural correlate for processing individual faces in infancy. Double-peaked negative components in the N170-N290 time range have been reported for children (Taylor, Batty, & Itier, 2004), but not for infants so far. Implications of the current results for face representations during infancy will be discussed.

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33.565 **Supra-additive contribution of shape and texture to individual face discrimination as revealed by electrophysiological periodic visual responses** Milena Dzhelyova[1](dzhelyova@yahoo.com), Bruno Rossion[1]; [1]University of Louvain

Face perception depends on two sources of information – 3D shape and surface-based cues (texture, color). According to behavioral studies, both of them equally contribute to discrimination of individual faces (O'Toole, Vetter & Blanz, 1999). However, these behavioral measures can be contaminated by many factors, not allowing to distinguish and to quantify the respective contribution of each source of information. Using an established method of manipulating facial images (Tiddeman, Burt, & Perrett, 2001), four individual faces (2 males) were morphed with another 10 same-sex faces varying shape only, texture only or both. Electroencephalogram (EEG) was recorded from 10 participants during a rapid periodic oddball visual stimulation, providing an objective, implicit and robust quantifiable measure of visual discrimination (Liu-Shuang, Norcia & Rossion, in press). Stimuli were presented in 80 sec long trials, in which the same face (one of the 4 faces) was shown four times consecutively and the fifth face (the oddball) was one of the corresponding morphed faces, thus resulting in a sequence AAAABAAAACAAAAD. The base frequency F was 5.88 Hz and the oddball frequency 1.18Hz (5.88Hz/5) and its harmonics (nF/5) were used to measure individual face discrimination. This individual face discrimination response was observed at occipito-temporal sites, particularly over the right hemisphere. While shape was also discriminated at right occipito-temporal electrode sites, surface information was coded bilaterally (Jiang et al., 2009). However, and most importantly, shape and texture changes alone were associated with much weaker responses than when both sources of information were combined, revealing a supra-additive effect of the contribution of the two facial aspects to the discrimination of individual faces. Thus, these results suggest that the two kinds of information combined are necessary to provide a full face identity, i.e. face identity being more than the sum of the contribution of shape and surface cues.

33.566 **Contributing Factors of Person Recognition in Natural Environments** Carina A. Hahn[1](achahn30@gmail.com), P. Jonathon Phillips[2], Alice J. O'Toole[1]; [1]The University of Texas at Dallas, [2]National Institute of Standards and Technology

Little is known about recognizing moving people in naturalistic environments. We examined recognition as it occurs as a person approaches from a distance. Participants were visually familiarized with 30 identities. Recognition was tested subsequently with 8s videos of 60 people (half familiar) walking toward a camera (see supplementary material). The quality of identity information in the face and body varied naturally across the video sequence as the viewing distance changed. With this paradigm, we examined: 1) how the accumulation of diverse identity-related information affects recognition accuracy, and 2) the relative contribution of the face and body on recognition over the video's temporal sequence. In the whole-video recognition test, participants viewed entire videos, making familiarity judgments at three equally spaced time-points. Performance (d') was above chance and improved as people advanced toward the camera. In the segment test, participants viewed only one part of the video (beginning, middle, or end). Combined, the results from these two conditions indicated that the time of the response (beginning, middle, or end) predicted accuracy, rather than the amount of video seen. This suggests that the video segment immediately preceding a response determined recognition accuracy, with no evidence that people accumulated identity information across segments. Next, we examined the contribution of faces and bodies to recognition by blurring faces or bodies at test. Accuracy with faces-only was substantially better than with bodies-only and equaled performance in condi-

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tions where the whole person was seen. Notably, accuracy with faces-only improved as people approached the camera, whereas accuracy with bodies-only remained stable but above chance (see supplementary material). In summary, when viewing someone approaching in natural environments, people do not incorporate identity information over time. Instead, they rely primarily on close-up views of the face and the information viewed most recently, even with useful identity information across viewing distances.

33.567 Visual masking with faces: Interruption of a trailing mask at critical SOA does not reduce masking.

Marwan Daar[1](mdaar@yorku.ca), Hugh Wilson[1]; [1]Centre for Vision Research, York University

Modern theories of visual masking incorporate mechanisms that interefere with the consolidation of a target pattern into a conscious percept, and propose that feedback may be involved (Enns, 2004; Breitmeyer, 2007). To explore this, we conducted a series of experiments where we measured face identity discrimination thresholds in the central visual field under various masking conditions with face masks. In our first experiment (n=4), we examined masking as a function of SOA (stimulus onset asynchrony) in a standard backward masking paradigm, and compared it to common onset masking with a trailing mask. In this latter condition, the target and mask appeared at the same time, and after 33 ms, the target disappeared while the mask remained visible. In the SOA condition, peak masking occurred at an SOA of 58 ms, and in the trailing condition, masking equivalent to that of the peak SOA condition was found with a trailing mask duration of 58 ms and did not change as the trail was increased up to 600 ms. In Experiment 2, we tested seven observers in a modified trailing condition in which we briefly removed the masking stimulus for varying intervals, centered around the 58 ms point found to be critical in the previous SOA condition. When compared to an uninterrupted trail, we found no reduction in masking, with "mask gaps" as wide as 58 ms (p = 0.95). These results show that the effect of a trailing mask cannot be explained only by its presence at the critical SOA. We explore our findings in the framework of reverberant feedback loops.

33.568 Early Learning in Infancy Influences Children's Face Processing Several Years Later

Hillary Hadley[1](hhadley@psych.umass.edu), Charisse B. Pickron[2], Lisa S. Scott[3]; [1]Department of Psychology, College of Natural Sciences, University of Massachusetts, Amherst, [2]Department of Psychology, College of Natural Sciences, University of Massachusetts, Amherst, [3]Department of Psychology, College of Natural Sciences, University of Massachusetts, Amherst

The ability to differentiate between exemplars from an uncommonly experienced face group declines from 6 to 9 months of age. This decline in discrimination is absent if between 6 and 9 months infants receive training with individually labeled faces. Individual-level labels can also facilitate discrimination after infants are trained with non-face objects (strollers). Moreover, learning objects and faces at different levels during infancy changes the way the brain responds to the categories of trained stimuli. However, it is currently unclear whether this training is sufficient to create lasting behavioral or neural changes. For the present investigation, 4- to 5-year-old children trained as infants with monkey faces (n=23), strollers (n=20) and a control group (n=35) completed a behavioral discrimination task as well as an inversion task while for human faces, monkey faces and strollers while Event-Related Potentials (ERPs) were recorded. Although children did not exhibit long lasting behavioral or neural effects for the trained stimuli (monkeys or strollers) there were significant group differences in their responses to human faces. Behaviorally, children who were trained at the individual-level (regardless of training stimulus) exhibited significantly faster reaction times to human faces relative to category-level training and the no-training control group. In addition, children who were trained with individually labeled monkey faces as infants exhibited an adult-like N170 inversion effect such that there was a greater N170 to inverted relative to upright human faces. Children in all other groups showed the opposite N170 pattern. These results suggest that training at the individual level with monkey faces and strollers in infancy influences response time for human faces in childhood. However, training with monkey faces but not strollers influences neural responses to human faces in childhood. This dissociation between behavior and brain is discussed in relation to the development of face and object processing and expertise.

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Face perception: Whole and parts

Sunday, May 18, 8:30 am - 12:30 pm
Poster Session, Pavilion

33.569 Reverse-engineering the Face-Space: Discovering the Crucial Features for Face Identification

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Despite extensive research, there is little knowledge as to which facial features are critical for face identification. Here we present a "reverse engineering" approach to this problem: testing which features should be changed such that a modified face is no longer recognized as the original person. Based on the Face-Space theory (Valentine, 1989), we constructed a multidimensional feature space, wherein each dimension is a different feature and each face is represented as a feature vector. To do this, we defined a set of 20 features (e.g. eyebrow thickness, skin texture, lip thickness etc.) and asked subjects to assign values to these features for each face (e.g, rate eyebrow thickness on a "very narrow - very thick" scale). To modify faces, the distinctive (i.e. far from average) features in each face were replaced, by copying features with "opposite" values, from other faces in the data-set. To assess whether distance in face space was correlated with perceptual similarity judgements, face identification was measured by presenting pairs of pictures, before and after modification, and asking subjects to rate the extent to which the two faces are same or different people. Results show that distances between feature-vectors of faces were correlated with perceptual similarity judgments between faces, validating the dimensions of the face space. This correlation increased when each feature was weighted according to its inter-rater reliability measure. Specifically, a sub-set of 7 features, which include hair color and length, eyes shape and color, eyebrows-thickness, ears-protrusion and lip-thickness, accounted for most of the variability in perceptual similarity scores between faces. We conclude that these features, to which we are most sensitive, may be critical for face identification.

33.570 Perceptual interactions between dynamic facial features

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We are frequently exposed to correlated eye and mouth movements such as the characteristic changes accompanying yawning, sneezing or laughing. However, it is not clear whether the visual system is sensitive to these dynamic regularities, encoding facial behavior relative to a set of dynamic global expression prototypes, or whether it simply forms a piecemeal description of feature states over time. We sought to address this question by looking for evidence of perceptual interactions between dynamic facial features. Participants viewed two avatar faces side-by-side, a standard and a comparison stimulus. Both faces opened and closed their eyes periodically at 1.25 Hz. The mouth on the comparison stimulus remained closed throughout. The eyelid transitions (open-to-closed and vice versa) exhibited by the standard stimulus always lasted 140 ms. Eyelid transitions for the comparison stimulus varied in duration from 20 ms to 260 ms in steps of 40 ms. Participants were asked to report whether the standard or comparison blinked faster. The perceived speed of the standard eyelid transition was inferred from the point of subjective equality (PSE) on the resulting psychometric function. Perceived speed was measured both upright and inverted, at four relative phase relationships. The presence of the mouth movements caused illusory slowing of the eyelid movements, but only when the standard face was presented upright at 180° and 270° phase relationships. Subsequent experiments demonstrate i) that illusory slowing of the eyelids is produced by mouth movements with both sinusoidal and constant velocity kinematic profiles; ii) that the presence of eyelid motion also causes illusory slowing of mouth movements; iii) that individuals with autism spectrum disorders are not susceptible to the illusory slowing. Perceptual interactions between facial features reveal face-specific encoding mechanisms that integrate dynamic features into expression prototypes, encompassing global properties of facial change.

33.571 **Facial** movement optimizes part-based face processing by influencing eye movements Naiqi Xiao[1](naiqi.xiao@mail.utoronto.ca), Paul Quinn[2], Qiandong Wang[3], Genyue Fu[3], Kang Lee[1]; [1]Department of Applied Psychology and Human Development, University of Toronto, [2]Department of Psychology, University of Delaware, [3]Department of Psychology, Zhejiang Normal University

Much of our understanding about face processing has been derived from studies using static face pictures as stimuli. It is unclear to what extent our current knowledge about face processing can be generalized to real world situations where faces are moving. Recent studies have shown that facial movements facilitate part-based, not holistic, face processing. The present study, using high-frequency eye tracking and the composite face effect paradigm, examined the overt visual attention mechanisms underlying the effect of facial movements on part-based processing. In the moving face condition, participants first remembered a face from a 2-second silent video depicting a face chewing and blinking. They were then tested with a static composite face. The upper and lower halves of the composite face were from different models, which were displayed either aligned or misaligned. Participants judged whether the upper half of the composite face was the same person as the one they just saw. The static face condition was identical to the moving face condition except that the to-be-learned faces were static pictures. Participants' eye movements during learning and testing were recorded. Consistent with previous findings, learning moving faces led to a smaller composite effect than learning static faces, suggesting that facial movements facilitated part-based face processing. In addition, participants exhibited longer looking time for each fixation (i.e., deeper processing) while learning the moving relative to the static faces. Further, each participant's upper face looking time advantage while learning moving relative to static faces positively predicted the part-based face processing increase engendered by facial movements. The association was only observed in the aligned but not the misaligned condition, indicating that fixating the moving upper face half was specific to reducing the interference from the aligned lower face half. These results indicate that facial movement optimizes part-based face processing by influencing eye movements.

33.572 **Dynamic facial expressions are not necessarily processed holistically** Martin A. Giese[1](martin.giese@uni-tuebingen.de), Eva R.M. Joosten[1]; [1]HIH & CIN, Dept of Cogn. Neurology, University Clinic Tübingen, Germany

Face perception studies support a holistic/part-based model of face perception, where holistic and part-based processing make parallel and separable contributions to face perception [1]. However, it remains unclear which exact aspects are included in holistic processing. Many studies have concluded that facial expressions are processed holistically [e.g. 2,3,4], but most of them have used static stimuli, opposed to the fact that natural facial expressions are highly dynamical. Using a novel technique to control the dynamics of individual face parts separately, we studied the integration of dynamic facial components in expression recognition. METHODS. From a video database with natural dynamic facial expressions we constructed a morphable model that permits to control the emotional style and timing of different face parts separately. The technique exploits active appearance models [5] that were trained separately on different parts of the face, so that shape variations (e.g. of the eye or mouth) could be characterized by low dimensional vectors. In a classification experiment, by morphing between neutral and emotionally expressive parts, we determined the recognition thresholds for face parts and the holistic perception of the whole face. RESULTS AND CONCLUSION. The thresholds for the perception of facial expressions were equal for holistic faces and combinations of spatial parts, as long as the eyes were present (all p's > 0.14). In a quantitative analysis we did not find indications of a holistic processing of dynamic emotional expressions. References: [1] Pieper et al., Front Psychol, 3, 2012 [2] White, Am J Psychol, 112(3), 1999 [3] Calder et al. J Exp Psychol Hum Percept Perform, 26(2), 2000 [4] Tanaka et al., Cogn Emot, 26(6) , 2012 [5] Cootes et al., IEEE Trans Pattern Anal Mach Intell, 1998.

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33.573 **The inversion effect as a function of orientation information in emotional face and body recognition** Carol Huynh[1](carol.huynh@my.ndsu.edu), Christopher Tonsager[1], Benjamin Balas[1]; [1]North Dakota State University

Face and body perception are both disrupted by picture-plane inversion – 180-degree rotation leads to poorer recognition and discrimination. For face stimuli, the inversion effect appears to be carried by horizontally-oriented structures (Goffaux & Dakin, 2010), which appear to also carry more information for identity than vertical orientations. Here, we asked whether the inversion effect for faces and bodies expressing different emotional expressions (happy and sad) was carried by different orientation sub-bands. Specifically, we measured observers' performance at classifying emotional faces and bodies that were filtered to include either horizontal structure, vertical structure, or both orientation bands. Two groups of participants completed the face (N=22) and body (N=25) tasks, in each case asking participants to distinguish happy and sad stimuli. In both tasks, participants viewed stimuli in a fully randomized order for 2000ms each and classified images by emotion as quickly and as accurately as possible. Picture-plane orientation varied across experimental blocks while filter orientation was randomized within blocks. The results of Experiment 1 revealed that inversion negatively impacted accuracy for both horizontally-filtered ($p<.001$) and vertically-filtered ($p<.001$) faces, but only marginally affected faces containing both orientation information ($p=.051$). By contrast, in Experiment 2 we found that inversion significantly lowered accuracy for horizontally-filtered bodies ($p=0.001$), but that inversion significantly improved accuracy for vertically-filtered stimuli ($p<0.001$). Bodies with both orientations present exhibited no inversion effect. We conclude that the inversion effect's dependence on orientation sub-bands differs for faces and bodies, which may reflect distinct "tuning" of face and body representations for low-level image features. Observers may also adopt different strategies for processing faces and bodies, leading to differential impact of orientation filtering as a function of stimulus category. Body inversion could have led to differential use of the upper vs. lower body, for example.

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33.574 **Does acquisition of holistic processing for novel objects depend on experience with diagnostic parts?** Chua Kao-Wei[1](kaochua@gmail.com), Jennifer Richler[1], Isabel Gauthier[1]; [1]Vanderbilt University

One hallmark of perceptual expertise is holistic processing, wherein objects are processed as wholes rather than by individual features. It has been suggested that holistic face processing could arise from a strategy of attending to all face parts (Curby et al., 2012, Richler et al., 2011). In a training study with two novel-race faces, we reported that holistic face processing depends on experience attending to diagnostic face parts, and is found even for combinations of face parts never seen together (Chua et al., VSS2013; under revision). We extend this paradigm to two categories of novel objects (Greebles) that should not be processed holistically before training. Fifty-one subjects learned to individuate objects from two visually distinct Greeble categories, where diagnostic information was in complementary halves (e.g., if diagnostic information was in the top half for one Greeble category, then it would be in the bottom for the other category). We then measured holistic processing in the composite task with new Greebles made up of aligned or misaligned diagnostic or non-diagnostic parts. A control group ($n=38$) with no prior exposure to Greebles also performed the composite task. In a within-subjects analysis of the composite task for trained subjects, we found no difference in holistic processing elicited by composites made of diagnostic vs. non-diagnostic Greeble parts (diagnosticity x alignment x congruency interaction in d'), $F(1,50) = 1.33$, $p = 0.26$, $\eta p2=.03$. However, Greeble training led to increased holistic processing relative to the control group, $F(1,87) = 7.45$, $p <0.01$, $\eta p2=.08$, showing that individuation training increased holistic processing of non-face objects. One explanation for the difference between these results and those we obtained with novel-race faces is that the two Greeble categories may not have been sufficiently distinctive, being distinguished by the shape of the non-diagnostic contour rather than the diagnostic parts themselves.

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33.575 The eye-size illusion: Psychophysical characteristics, generality, relation to holistic processing, and a role for visual experience
Kang Lee[1](kang.lee@utoronto.ca), Wen Xiao[2], Genyue Fu[3], Paul Quinn[4], Yu-hao Sun[5], Naiqi Xiao[1], Qiandong Wang[3], Guowei Chan[3], Olivier Pascalis[6], Fabrice Damon[6]; [1]Dr. Eric Jackman Institute of Child Study, OISE, University of Toronto, [2]School of Preschool Teacher Education, Zhejiang Normal University, [3]School of Education, Zhejiang Normal University, [4]Department of Psychology, University of Delaware, [5]Department of Psychology, Zhejiang Sci-Tech University, [6]LPNC, CNRS, Université Grenoble Alpes

Rakover (2011) observed a novel eye-size illusion: when increasing the size of a face but keeping the size of its eyes unchanged, the eyes are perceived to be larger than in the original face. Here, we systematically manipulated the face size and found that the magnitude of this illusion linearly changed as a function of the face frame size (Experiment 1). Additionally, the same magnitude of an illusion was observed for the perception of the size of the mouth when we changed the face frame but kept the mouth size constant (Experiment 2). Further, we investigated whether the magnitude of the illusion was affected by stimulus inversion and differential experience with particular categories of faces. We found that when the faces and eyes were presented upside down, the magnitude of the illusion was significantly reduced in both Chinese participants and Caucasian participants (Experiment 3). We also found that the illusion was more salient with own-race and own-age faces versus other-race and other-age faces (Experiment 4). The illusion reflects holistic processing because the perception of eye or mouth size occurs in the relational context of the whole face; when the face is seen upside down, thereby disrupting holistic processing, the magnitude of the illusion is reduced. The presence of other-race and other-age effects additionally suggests that experience plays a role in producing the illusion.

33.576 Hemispheric specialization for holistic processing of faces in normal and prosopagnosic observers?
Tina Liu[1,2](tongliu@andrew.cmu.edu), Matt Oxner[2], William Hayward[2], Marlene Behrmann[1]; [1]Department of Psychology and Center for the Neural Basis of Cognition, Carnegie Mellon University, [2]Department of Psychology, University of Hong Kong

Holistic processing has been considered a property of the right hemisphere and associated with face perception whereas part-based processing has been considered a property of the left hemisphere and associated with word reading in Caucasian readers. This hemispheric profile may not hold for Chinese individuals given their greater reliance on holistic processing of faces and the bilateral hemispheric engagement for reading. To explore the hemispheric basis of holistic processing of faces and examine whether this holds equally for Caucasian and Chinese observers, we created composite stimuli, split down the vertical midline, by pairing one left half with the right half of another face of the same gender and race. We included both Chinese and Caucasian faces to account for possible other-race effects as well. Participants made same-different judgments about the left or the right halves of two sequentially presented composite faces, in two conditions: when the face halves were aligned or misaligned. For Chinese and Caucasian observers, a larger congruency effect for the aligned than misaligned faces was found (i.e., alignment by congruency interaction), suggesting strong holistic processing of left-right composite faces. However, there was neither effect of the visual field of the face half to be judged (i.e., no hemispheric modulation), nor of race of the participants. These findings reflect equal participation of both hemispheres in face perception and this held across both groups. This left-right composite face paradigm was further validated in individuals with congenital prosopagnosia whose performance in this task was impaired compared to the control observers. Taken together, holistic processing was demonstrated using left-right composite faces for the first time. The magnitude of holistic processing was equivalent for face halves presented in either visual field (processed in the corresponding hemisphere) and for all participants with normal face perception but not for the congenital prosopagnosia observers.

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33.577 Holistic processing of faces in the composite task depends on size
David Ross[1](david.ross@vanderbilt.edu), Isabel Gauthier[1]; [1]Department of Psychology, Vanderbilt University

Faces, more than other objects, are processed holistically. There is some evidence that holistic processing is strongest for faces at a conversational distance, dropping off for faces that are further away (McKone, 2009). However, the only previous study of this question used tasks that have not been directly related, theoretically or experimentally, to other measures of holistic processing. Here, we use a well validated and frequently used paradigm – the composite task – to measure the effect of viewing distance on holistic processing. Participants (n=99) judged whether halves of sequentially presented face composites matched, ignoring the other half, which could be congruent or not with the correct response. Holistic processing was defined as the congruency effect for aligned relative to that for misaligned parts. We used a within-subjects design with 4 blocked levels of size: the largest face size corresponded to a viewing distance of 2 meters, and the smallest face size corresponded to a distance of 24 meters. Holistic processing varied linearly with size (Figure 1), as supported by an interaction between alignment, congruency and linear contrast for face size, $F(1, 98) = 4.36$, $MSE = 1.34$, $p < 0.05$, $\eta p2 = 0.04$. There was no holistic processing at the smallest size (visual angle = 0.35o; ηp2= .000; p=.77) and considerable holistic processing at the largest size (visual angle = 4.14o; ηp2= .09; p=.003). The interaction of congruency with size was entirely driven by the aligned condition (ηp2= .05; p=.03) and was not observed in the misaligned condition (ηp2= .005; p=.47). Size influences the magnitude of holistic processing in the composite task, suggesting it should be considered when comparing across studies and carefully controlled in individual differences studies. More work will be necessary to understand if this size effect is due to experience or general constraints of selective attention.

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33.578 Differences in Face Recognition Ability Predicts Patterns of Holistic Face Processing in Children
Sherryse Corrow[1](sherryse.corrow@eyecarecentre.org), Tobias Donlon[2], Jordan Mathison[2], Vanessa Adamson[2], Albert Yonas[2]; [1]Ophthalmology and Visual Sciences, University of British Columbia, [2]Institute for Child Development, University of Minnesota

DeGutis and colleagues (2012) have demonstrated that adults with developmental prosopagnosia show a typical holistic processing effect for the mouth, but not for the eye region. These findings are consistent with previous speculations that holistic processing of the eye region may be particularly important for successful face recognition. The present study examined 30 children, recruited based on their exceptionally high or low scores on the Cambridge Face Memory Task–Children (CFMT-C) from a database of more than 500 children. These children were separated into two groups roughly matched for age: those that performed very well at face recognition (high performers; N=15) and those that performed very poorly at face recognition (low performers; N=15). Average scores on the CFMT-C for each group were 91.31% (sd=5%) and 69.27% (sd=8%) respectively. For each group, we examined holistic face processing using the Part-Whole Task (Tanaka et al., 2010). This task examines the ability to recognize face parts (e.g. the eyes) both in isolation and in the context of the whole face, both of which differed by only one feature. As expected, the high performing group showed an overall holistic advantage, with greater accuracy on whole trials than part trials [$t(14)=3.82$, $p<0.01$]. This finding remained marginally significant when examining eye and mouth trials separately [Eye Trials: $t(14)=1.97$, $p=0.068$; Mouth Trials: $t(14)=2.01$, $p=0.064$]. Similar to the findings of DeGutis and colleagues (2012), the low performing group also showed an overall holistic advantage [$t(14)=3.74$, $p<0.01$]. However, this holistic advantage was carried by a holistic effect for mouth trials [$t(14)=3.1$, $p<0.01$] but not eye trials [$t(14)= -0.29$, n.s.]. These results replicate the finding that holistic processing of the eye region is particularly important for successful face recognition and may be impaired in cases of prosopagnosia. Furthermore, these data demonstrate the similarities in holistic processing between children and adults.

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33.579 Age-related effects on selective processing of horizontal structure in whole-face context
Allison B. Sekuler[1](sekuler@mcmaster.ca), Matthew V. Pachai[1], Sarah E. Creighton[1], Patrick J. Bennett[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University

Younger observers use horizontal structure in the eyes/eyebrows when identifying faces (Pachai et al, VSS 2013), and the extent to which they do so is correlated with identification performance (Pachai et al., Front Psychol 2013). However, it is unknown whether the age-related decline in face identification accuracy is related to a reduced ability to utilize horizontal structure. Obermeyer et al. (Front Aging Neurosci 2012) showed poorer discrimination of horizontally filtered faces in older relative to younger adults, suggesting that older observers use diagnostic horizontal information less efficiently when the target band is specified precisely. It remains

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unclear, however, if there are age-related differences in the extraction of horizontal structure from the more ecologically valid case of intact faces. We examined this issue using a 6AFC identification paradigm in which the target face was filtered on a given trial to retain information in only the horizontal, vertical, or oblique orientation bands (bandwidth = 45 degrees). Across two groups, these stimuli were presented alone (face context absent) or combined with orthogonal facial structure obtained by averaging the six possible faces (face context present). For both groups, only a specific orientation band was diagnostic on a given trial, but the context present group had to extract this information from a whole face without knowing which orientation band was informative. Context affected the selective use of horizontal structure differently in the two age groups. Specifically, adding context caused young observers to be more reliant on horizontal structure, whereas it caused older observers to be less reliant on horizontal structure. This result suggests that the age-related deterioration in face identification is driven largely by decreased selective extraction of diagnostic information from intact stimuli, and is consistent with previous results suggesting that seniors rely more on holistic information in faces (Konar et al., Vis Res, 2013).

Acknowledgement: NSERC, CIHR, Canada Research Chairs Programme

33.580 **Why the Long Face? The critical role of vertical configural relations in face 'barcodes' for recognition** Morgan Spence[1](morgan.spence@uqconnect.edu.au), Katherine Storrs[1], Derek Arnold[1]; [1]Perception Lab, School of Psychology, The University of Queensland

Humans are experts at face recognition. The mechanisms underlying this complex capacity are not fully understood. Recently, it has been proposed that face recognition may be supported by a coarse-scale analysis of visual information contained in horizontal bands of contrast distributed along the vertical image axis – a biological facial 'barcode' (Dakin & Watt, 2009). A critical prediction of the face barcode hypothesis is that the distribution of image contrast along the vertical axis will be more important for face recognition than image distribution along the horizontal axis. A series of experiments are presented examining famous face recognition impairments from selectively disrupting image distributions along the vertical or horizontal image axis using a novel animation paradigm. Results showed that disrupting the image distribution along the vertical image axis was more disruptive for recognition than matched distortion along the horizontal axis. Consistent with the barcode hypothesis, these results suggest that human face recognition relies disproportionately on appropriately scaled distributions of image contrast along the vertical image axis. These findings contribute to an emerging understanding of low-level models of human face recognition.

33.581 **Mind the gap: behavioral measures and phenomenology of the composite face illusion** Talia Retter[1](tlretter@gmail.com), Bruno Rossion[1]; [1]Psychological Sciences Research Institute (IPSY)/Institute of Neuroscience (IoNS), University of Louvain

Holistic face perception is well-evidenced, although methods for its quantification remain debated. One measurement, provided by the composite face effect (CFE), reflects impaired performance at recognizing two upper face halves as identical when they are aligned (compared to misaligned) with lower face halves of differing identities (Young et al., 1987; Rossion, 2013 for review). The validity of this measure is challenged by two apparently contradictory goals: a composite face should be perceived as a whole entity, yet the precise area of an upper face half must be defined for task performance. Here, we investigated the impact of a small gap between upper and lower face halves in two complimentary experiments. First, 16 participants were tested with gap and no-gap stimuli in a standard delayed matching composite face task. Although both stimuli conditions produced a substantial CFE, this was significantly larger for no-gap stimuli. Second, we tested whether this larger effect reflected better integration of facial halves. Ten participants performed a forced-choice perceptual judgment, determining which of two simultaneously displayed faces was the veridical face (i.e., with both halves from the same original identity) and which the composite face. Perceptual judgments for no-gap stimuli approached ceiling (91%); in contrast, with a gap, participants were almost unable to identify the veridical face (61%). This effect was not only due to low-level segmentation cues at the border of no-gap face halves, because stimuli inversion decreased performance in both conditions (no-gap: 84%; gap: 52%). These observations indicate that, paradoxically, facial halves are integrated more naturally in stimuli with a gap. Therefore, the larger CFE for no-gap stimuli is likely to emerge primarily from a lack of clear definition of an upper face half. Taken together, these results indicate that composite face stimuli with a gap provide a more accurate measurement of holistic face perception.

33.582 **Attentional scope modulates unconscious processing: evidence from breaking continuous flash suppression** Sol Z. Sun[1](sol.sun@mail.utoronto.ca), Susanne Ferber[1,2]; [1]University of Toronto, [2]Rotman Research Center at Baycrest

Visual attention is a core cognitive faculty facilitating other aspects of visual experience such as object recognition and conscious awareness. However, the precise nature between these aspects of visual cognition is unclear. Studies have examined unconscious object perception using a binocular rivalry paradigm called continuous flash suppression (CFS). These studies demonstrate that stimuli receiving preferential unconscious processing require less time to break through interocular suppression. However, few studies have examined whether attention proceeds without awareness and influences object perception. This study investigated whether well-established global/local attentional biases influence processing of faces without awareness. Previous research demonstrates that global bias facilitates holistic face perception. Therefore, it was predicted that global bias would result in shorter suppression times for faces under CFS. Participants were presented with Navon images (large letters composed of small letters), and made same/different judgements based on attention to the big letter (global) or small letter (local). In CFS trials, participants were presented with Mondrian-style arrays of flashing circles to one eye, and a face to the other. They identified whether the face was to the left or right of the fixation. A control condition was included to examine the possibility that differences in suppression time were due to general differences in detection sensitivity attributable to global/local bias, not face processing per se. In control trials, the Mondrian array and face were presented to both eyes, emulating the experience of CFS under non-rivalrous conditions. Results showed that in CFS trials, detection times for face stimuli were shorter under global bias, relative to local bias. Additionally, this difference was not observed in the non-rivalrous control condition. These results suggest that global attentional bias does not require conscious awareness to influence holistic face perception. These results show that qualitatively similar computations are involved in both conscious and unconscious stimulus processing.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada (NSERC), Canadian Institutes of Health Research (CIHR)

33.583 **Moving biological stimuli (not just faces) amplify inversion effect sizes** Daniel W. Piepers[1](d.piepers@uws.edu.au), Catherine J. Stevens[1,2], Darren C. Burke[3], Rachel A. Robbins[1]; [1]School of Social Sciences and Psychology, University of Western Sydney, NSW, Australia, [2]The MARCS Institute, University of Western Sydney, NSW, Australia, [3]School of Psychology, University of Newcastle, NSW, Australia

Turning a face upside-down disrupts our ability to accurately perceive changes in spacing and feature shape information, and has been suggested to disrupt configural/holistic processing. When a face engages in motion the shape of the features and spacing between them undergo continual variation. However, little is known about the effect that inversion has on this added level of configural change within a moving face or whether this added level of change impacts on the perception of other non-face stimuli in a similar way. The aim of the current experiment was to explore the effect of inversion on moving and static unfamiliar faces and two comparable classes of biological stimuli - human bodies and dogs - in a long-term memory recognition task. It was hypothesised that the added disruption of spacing and feature shape change due to motion would increase inversion effect sizes for moving (compared to static) faces and bodies, but not dogs. Results revealed significantly larger inversion effects in inverse efficiency (IE) for all moving (compared to static) stimulus types. For moving faces (and perhaps bodies) this increased delay in IE may come about as a result of increased difficulty in tracking configural and feature shape change in an upside-down face. However, this interpretation seems unlikely given that a similar increase in IE was also found between static and moving dogs and patterns in inversion effect size differences between stimulus types remained consistent in the static and moving groups. The findings suggest that face perception remains quantitatively similar to whole-body perception and quantitatively dissimilar to dog perception regardless of whether the stimuli are static or moving.

Acknowledgement: I would like to acknowledge my PhD stipend granted to me through the APA (Australian Postgraduate Award) as well as the University of Western Sydney for their top up of this award. I would also like to acknowledge the School of Social Sciences and Psychology at the University of Western Sydney for the allocation of the funding and resources needed for this research. Finally I would like to acknowledge the MARCS institute at the University of Western Sydney for their continuing support.

Sunday Afternoon Talks

Eye movements: Perisaccadic perception

Sunday, May 18, 2:30 - 4:15 pm
Talk Session, Talk Room 1
Moderator: Eli Brenner

34.11, *2:30 pm* **Spatiotopic representations emerge from remapped activity in early visual areas** Eckart Zimmermann[1](ec.zimmermann@fz-juelich.de), Ralph Weidner[1], Gereon Fink[1,2]; [1]Cognitive Neuroscience, Institute of Neuroscience and Medicine (INM-3), Research Centre Jülich, Germany, [2]Department of Neurology, University Hospital Cologne, Germany

How the visual world remains stable across the frequent movements of the eyes is one of the long-standing mysteries in neuroscience. We tested whether an active remapping process constructs a spatiotopic neural representation, which is reflected in behavior and might thereby enable visual stability. We combined behavioral visual adaptation and fMRI - adaptation. This combination allowed tracking spatiotopic and retinotopic specificity across eye movements in both, neural activations and behavioral performance. Subjects saw an oriented gabor patch for 3 seconds, followed by a saccade target. Subjects were required to keep fixation for further 1000 ms to give the perceptual system time to build up a spatiotopic representation. Following the saccade, a probe gabor patch was flashed and subjects had to judge its orientation. The probe gabor patch was shown either in the same spatiotopic position as the adapter, in the retinotopically matched position or in a neutral control condition. We contrasted neural activation and behavioral responses to baseline trials in which no adapter was shown. We found behavioral adaptation in both the retinotopic and the spatiotopic condition. Significant clusters of neural adaptation were found in both conditions in contralateral visual areas V1-V4. In order to establish adaptation in the hemisphere which was not adapted before the saccade, adapter activity must have been actively remapped contingent to the saccade. No adaptation was found in the control condition, neither in behavior nor in neural activations, thus ruling out global adaptation which spreads unspecifically across the visual cortex. The remapping to be behaviorally relevant needed a certain duration to build-up. The results show that visual features are actively remapped in early visual areas across saccade eye movements.

34.12, *2:45 pm* **Saccadic remapping of object-selective information** Benjamin Wolfe[1](bwolfe@berkeley.edu), David Whitney[1]; [1]University of California at Berkeley

Studies of saccadic remapping dispute whether remapping is a local attentional facilitation (Rolfs et.al, 2010; Cavanagh et.al, 2010) or if it is specific to the object targeted with the saccade (Melcher 2009; Burr and Morrone, 2011). We probed this question using the face aftereffect (FAE), where the perceived gender, emotion and identity of a face changes following foveal adaptation (Leopold et.al., 2001; Webster, 2004; Kovács et.al., 2005). To test this, we induced the FAE across saccades by briefly presenting different emotional faces (happy and sad) as presaccadic adaptors at 15º eccentricity, one each to the left and right of a central fixation dot, then cued subjects to saccade to a target on or near one adaptor. Once the saccade terminated, a test face was presented foveally and subjects judged whether the morphed test face was more happy or sad. Using the method of constant stimuli, we estimated the point of subjective equality (PSE) in each adaptation condition and compared the difference of PSEs as a measure of the FAE. All subjects showed a significant negative FAE for perceived emotion, despite the fact that the adaptor face was presented in the periphery and did not retinally overlap the test face. Crucially, the adaptor was removed from the screen as soon as the saccade began; therefore, the saccade-gated FAE that we observed must be induced presaccadically, suggesting that peripheral object-level information is acquired presaccadically. In addition, by varying the saccade target location on each trial and calculating saccade error, we estimated the spatial tuning of the presaccadic FAE; the effect diminishes as saccade error increases. That is, saccades needed to land on the peripherally presented adaptor face to produce a foveal FAE. Our results suggest that presaccadic remapping acquires information about the target object and that this information can bias postsaccadic perception.

Acknowledgement: NSF-GRFP

34.13, *3:00 pm* **Pre-saccadic motion integration between current and remapped locations** Martin Szinte[1](martin.szinte@gmail.com), Donatas Jonikaitis[1], Martin Rolfs[2], Patrick Cavanagh[3], Heiner Deubel[1]; [1]Allgemeine und Experimentelle Psychologie, Ludwig-Maximilians-Universität, Munich, Germany, [2]Bernstein Center for Computational Neuroscience & Department of Psychology, Humboldt-Universität, Berlin, Germany, [3]Laboratoire Psychologie de la Perception, Université Paris Descartes, Sorbonne Paris Cité, CNRS UMR 8158, Paris, France

We easily keep track of an attended object across saccades, even if its projection on our retinas changes every time we move our eyes. This ability is thought to rely on a deployment of attention before the eyes start to move, sampling both the object's current and its "remapped" location (i.e. the retinal location the object will have after the saccade, Rolfs et al., 2011; Jonikaitis et al., 2013; Hunt & Cavanagh, 2011). Here we report evidence for this bi-local sampling by showing that an attended motion signal can be integrated pre-saccadically with another signal presented at its remapped location. While preparing a saccade, observers viewed four random dot kinematograms, one of which was cued by the onset of a colored flash. Observers reported the direction of coherent motion signal at the cued location presented simultaneously with a second signal either at the cue's remapped location or at one of several control locations. Pre-saccadic discrimination of the cued motion signal increased only if we presented the second pulse at its remapped location and only if both signals shared the same direction. These results suggest that motion information is sampled and integrated from both the current and the post-saccadic retinal locations of an attended target even before the saccade begins. This is evidence of a mechanism that integrates features across different positions in space, provided they are expected to be from the same object.

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34.14, *3:15 pm* **Perisaccadic Response Modulations in Area V1 of the Macaque Monkey are stimulus-dependent** Steffen Klingenhoefer[1](steffen.klingenhoefer@physik.uni-marburg.de), Till S. Hartmann[2], Richard T. Born[2], Frank Bremmer[1]; [1]Neurophysics, Philipps-University, Marburg, [2]Neurobiology, Harvard Medical School, Boston

We perceive a continuous, stable visual environment in spite of frequent saccadic eye movements. Saccadic suppression, i.e. a reduction in the sensitivity of the visual system at the time of the eye movement, is widely believed to support this perceptual stability. The neuronal basis of this phenomenon is not well understood yet. Psychophysical data suggested an early suppression site, like the LGN or area V1, while electrophysiological studies provided mixed results pointing rather toward higher extrastriate and parietal areas. In this study we investigated the hypothesis, that the diversity of the reported results might be due to methodological reasons: In studies, in which strong saccadic suppression was observed, typically a brief single stimulus was flashed at random times in different trials ('flash stimulation'); no or only weak suppression was found when some form of continuous stimulation that started well before the eye movement (e.g. permanent natural images or ongoing flicker) was used ('continuous stimulation'). In the present study, we recorded multi-unit activity in area V1 of the macaque monkey and compared the perisaccadic response modulations in conditions of flash and continuous stimulation. Continuous stimulation caused rapid neuronal adaptation during fixation, i.e. an initial transient response after stimulation onset was followed by a rapid decline until a stable level of sustained activity was reached. This level was only slightly modulated perisaccadically. Typically, a small reduction in activity during the eye movement was followed by a postsaccadic enhancement. For flashed stimuli, however, we observed a strong modulation: perisaccadic stimuli elicited a response that was reduced in amplitude by more than half of the value obtained during fixation. Our results provide evidence that strong saccadic suppression effects can be observed early in the visual system, at least as early as in V1.

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34.15, *3:30 pm* **Masks cause compression of space for perception and saccade endpoints** Sabine Born[1](sabine.born.fr@gmail.com), Eckart Zimmermann[2], Patrick Cavanagh[1]; [1]Laboratoire Psychologie de la Perception, Université Paris Descartes, France, [2]Research Center Jülich, Germany

Previous research has reported dramatic localization errors around the time of an eye movement. Stimuli briefly flashed just before a saccade are perceived closer to the saccade target, a phenomenon known as perisaccadic compression of space (Ross, Morrone, & Burr, 1997). We have demonstrated that similar mislocalizations of flashed stimuli can be observed in the absence of saccades (Zimmermann, Fink, & Cavanagh, 2013): Brief probes were attracted towards a visual reference when followed by a mask. We extend these studies to examples with a pair of references that draw the probe into the gap between them. Strong compression was found when we presented the reference stimuli followed by the mask, whereas little or no compression occurred for the reference pair alone. When the two references were arranged vertically, horizontal mislocalizations prevailed. That is, probes presented to the left or right of the vertically arranged references were "drawn in" to be seen aligned with the references. In contrast, vertical localization of the probes remained almost unaffected by the mask. This finding may be related to reports of perisaccadic compression of space being stronger parallel than orthogonal to the saccade vector. In contrast, when we arranged the two references horizontally, we found vertical compression for stimuli presented above or below the references. But we also observed horizontal mislocalizations: Probes were more strongly attracted by the left reference. Finally, when participants were to indicate the perceived probe location by making an eye movement towards it, saccade landing points were compressed in a similar fashion as perceptual judgments, indicating that the oculomotor system followed the perceptual illusion. Our findings challenge pure oculomotor accounts of perisaccadic compression of space. We suggest that perisaccadic and perifixational compression of space both reflect how the visual system deals with disruptions and discuss the potential role of correspondence matching.

34.16, *3:45 pm* **Moving your head reduces perisaccadic compression** Maria Matziridi[1](m.matziridi@vu.nl), Eli Brenner[1], Jeroen B. J. Smeets[1]; [1]Faculty of Human Movement Sciences, VU University Amsterdam, The Netherlands

Stimuli that are presented briefly near the time of a saccadic gaze shift tend to be judged to have been closer to where the gaze ended than they really were. The resulting perisaccadic compression of perceived positions is probably related to uncertainty about the direction of gaze at the time of the flash. The larger the shift in gaze the stronger the compression, possibly because the uncertainty increases with the magnitude of the motor commands that give rise to the change in gaze. If so, then performing part of the gaze shift by moving one's head may decrease the compression, because the combined uncertainty of eye and head orientation in a combined eye-head gaze shift will be smaller than the uncertainty of the eye when it shifts gaze on its own. To test whether reducing eye-in-head movement by moving the head reduces perisaccadic compression for a given shift in gaze, we asked participants to shift their gaze between two positions, either without moving their head or with the head contributing to the change in gaze. We flashed targets around the time of the saccades and participants indicated where they saw these targets. Although allowing head movements did not affect the amplitude and velocity of the gaze shifts, the eye-in-head movements and their peak velocities were obviously larger when only the eyes moved, than when both the eyes and the head contributed to the change in gaze. There was also significantly more compression when only the eyes moved than when both the eyes and head moved. We conclude that moving one's head can reduce the magnitude of the systematic mislocalization that is observed near the time of rapid shifts of gaze.

34.17, *4:00 pm* **Saccades reset temporal integration windows** Andreas Wutz[1](andreas.wutz-1@unitn.it), Evelyn Muschter[1], Martijn van Koningsbruggen[1], David Melcher[1]; [1]Center for Mind and Brain Sciences (CIMeC), University of Trento

Dynamic vision must balance the need to accumulate sensory evidence over time and maintain stability of the current perceptual representation. Those opposing needs of the visual system can be subserved by an intricate interplay between rapid saccadic eye movements to and longer lasting fixations on the relevant parts of the visual environment. Here we investigate whether eye movements influence the ability to integrate successive visual input over time. We took advantage of a temporal integration paradigm that requires observers to perceptually bridge a short temporal gap between two rapid visual displays (missing element task: Di Lollo, 1980). We adjusted the temporal interval (24 ms) to threshold performance and then varied the temporal asynchrony between the onset of a fixation following a horizontal eye movement (8° visual angle from center) and the presentation of visual displays. The visual stimuli were presented at several time points within the lifetime of a typical fixation (0-25, 26-50, 51-75, 76-100 ms) or later in time (500-525 ms) with respect to fixation onset. As a control condition, observers had to detect the missing element within a combined presentation of both displays at the same time rather than temporally integrate information across displays. Temporal integration improved gradually within the first 100 ms from fixation onset and remained stable at predicted threshold performance later in time. In the control condition, however, detection was at ceiling independent of fixation to stimulus onset asynchrony. These results show that, unlike detection, the ability to integrate visual information over time depends on a rapid temporal window (~100 ms), reset by eye movements. Such a temporal integration window could provide stability of the current percept early within the lifetime of each new fixation.

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Perceptual organization: Neural mechanisms and models

Sunday, May 18, 2:30 - 4:15 pm
Talk Session, Talk Room 2
Moderator: Thomas Carlson

34.21, *2:30 pm* **What is the nature of the decodable neuromagnetic signal? MEG, Models, and Perception.** Thomas Carlson[1](thomas.carlson@mq.edu.au), Seyed Khaligh-Razavi [2], Nikolaus Kriegeskorte[2]; [1]Department of Cognitive Sciences, Macquarie University, Sydney, Australia, [2]MRC Cognition and Brain Sciences Unit, Cambridge, United Kingdom

In recent years, there has been increased interest in the use of pattern analysis methods with MEG to study visual processing. In the present study, we examined the explanatory power of several models of visual stimuli to study the nature of the decodable neuromagnetic signal. While their brain activity was recorded with MEG, participants were shown thirty abstract patterns constructed from multiple Gabor elements. The patterns varied along three dimensions (number of elements, local orientation, and orientation coherence among elements). From the MEG data, we measured "decodability" for all possible pair wise comparisons between stimuli as a function of time. We then compared decoding performance to each model's predictions. The first model was based purely on retinotopic stimulation. This was an excellent predictor, particularly early in the time series, thus showing retinotopic differences between stimuli is an important factor in determining decodability. We next examined three models used previously to study whether decoding methods in fMRI confer subvoxel spatial resolution (i.e. decoding orientation columns in visual cortex). These three models were based on local orientation disparity, the radial bias, and the horizontal/vertical preference. Interestingly all three models had little predictive power. We next tested HMAX, a biologically inspired model of early visual processing. The four early layers of HMAX provided a good account of the MEG data, indicating that global pattern differences, captured by HMAX's multiscale representation, contribute to decodability. Finally, we were interested in how decodability relates to perception. We created a perceptual model from behavioural ratings of the perceived similarity of the patterns. With the exception of the retinotopic model, similarity judgments were the best predictor before 100ms; and after 100ms, the best model. This final result demonstrates a close correspondence between perception and decodable brain activity measured with MEG – i.e. if it "looks" different, it's decodable.

34.22, *2:45 pm* **Sensitivity of early visual cortical neurons to edge visual concepts** Tai Sing Lee[1](tai@cnbc.cmu.edu), Corentin Massot [1], George Papandreou[2], Alan Yuille[3]; [1]Computer Science Department and Center for the Neural Basis of Cognition, Carnegie Mellon University, [2]Computer Science Department, Toyota Technology Institute , [3]Department of Statistics and Department of Computer Science, UCLA

Earlier neurophysiological studies by Pasupathy and Connor (1999, 2001, 2002) have showed that some V4 neurons are tuned to cue-invariant corner stimuli, suggesting that these neurons might be coding abstract concept of corners. Here, we studied whether and how neurons in early visual cortical areas are tuned to a more general set of edge concepts derived from natural images using statistical clustering techniques. By edge concepts, we mean cluster centers or prototypes of aligned edge contour segments extracted from the human-annotated edge maps of Berkeley segmentation. These concepts, totaling about 200, consist of lines, curves, junctions

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as well as more complex patterns. Each of these edge contour prototypes is associated with a particular mean image appearance patch where it comes from, and a set of principal components of all the appearance patches associated with the edge segments in that cluster. We presented these edge concepts, their associated appearance patches, and their first principal component patches to the receptive fields of V1, V2 and V3a neurons recorded from awake behaving monkeys using a semi-chronically implanted multi-electrode array. We found that the responses of a majority of the neurons in V1 and V2 to the contour patterns are correlated with their responses to the corresponding appearance patterns or principal component patterns (R =~0.5), suggesting that the neurons are tuned to these edge concepts. Individual neuron's coding of the edge concepts however is sparse in the sense that each will strongly prefer a few edge concepts, but is also distributed in the sense that it also responds moderately to many other concepts. The few V3a neurons recorded however appeared to respond strongly and transiently to the appearance patches but not the contour patches, suggesting that these neurons, with much larger receptive fields, might care more about surface concepts than edge concepts.

Acknowledgement: NIH

34.23, *3:00 pm* **Spontaneous visual cortex activity predicts eccentricity and is related to receptive field size**

Noah C Benson[1,2](nbe@sas.upenn.edu), Omar H Butt[1], Geoffrey K Aguirre[1]; [1]Department of Neurology, University of Pennsylvania, [2]Department of Psychology, University of Pennsylvania

Spontaneous "rest" fMRI signals have a spatial correlation structure in retinotopic visual cortex that resembles the radial organization of eccentricity. We tested if individual differences in measured eccentricity organization are reflected in resting state maps. Further, we examined if the spatial arrangement of resting state maps is better explained by common receptive field size as opposed to common eccentricity position. We collected rest (eyes-closed in darkness; 200 minutes) and retinotopic mapping data to 10° eccentricity (27 minutes) from 3 subjects at 3 Tesla. The data were registered to a common cortical surface atlas (fsaverage). The second principal component (SPC2) of the spontaneous correlations for each subject had radial structure aligned with the eccentricity direction. Using a cross-validation approach to determine an appropriate scaling factor, the SPC2 could predict eccentricity values out to 10° with 1.1° error in the group and 0.8° error in individuals, suggesting that spontaneous signals both resemble eccentricity organization and reflect individual differences. The SPC2 structure, however, was observed to plateau beyond 20°, unlike eccentricity which increases steadily with distance from the foveal confluence. We considered that SPC2 reflects not eccentricity per se, but receptive field size, which is in turn related to retinal ganglion cell (RGC) density in the retina. We obtained the inverse of the RGC density [Curcio & Allen, 1990, J. Comp. Neurol. 300:5-25] as an approximation of receptive field size and find that it is nearly identical in shape to traces of SPC2 along iso-polar angle lines. We conclude that the correlations in spontaneous fMRI signals reflect shared receptive field size across polar angle position and visual areas, and demonstrate that these correlations may be employed to predict eccentricity with high accuracy within 10° of the fovea.

Acknowledgement: 1 R01 EY020516-01A1

34.24, *3:15 pm* **Early Visual Cortex Assigns Border Ownership in Natural Scenes According to Image Context**

Jonathan R Williford[1](williford@jhu.edu), Rudiger von der Heydt[1,2]; [1]Department of Neuroscience, Johns Hopkins University, School of Medicine, [2]Krieger Mind/Brain Institute, Johns Hopkins University

Discerning objects from their backgrounds is a fundamental process of vision. The coding of border ownership in the early visual cortex is a neural correlate of this process. When stimulated with the contour of a figure, neurons with this correlate respond more strongly when the figure is on one side of their receptive field (the "preferred" side) versus the other (Williford & von der Heydt: Scholarpedia 8(10):30040, 2013). So far, border ownership coding has only been shown with simple displays of geometric shapes (e.g., squares). Here we studied border ownership coding with static images of natural scenes, using microelectrodes to record from isolated neurons in V1 and V2 of macaques. We found that subsets of V1 and V2 neurons indeed code for border ownership in complex natural scenes. Decomposition of local and context influences showed that the context-based border ownership signals correlated with those for the (locally ambiguous) edge of a square, but were weaker. We used stimuli with intermediate complexity along several dimensions to measure the relative influences of object shape, occlusion between objects, texture and color contrast to determine how they contribute to the border ownership signal strength. We found that border ownership signal decreases with the stimulus complexity. This was especially pronounced when comparing a simple isolated square with a C-shape, overlapping squares, and natural stimuli. There were also smaller decreases when changing from uniform squares to natural texture squares and from squares to silhouettes of natural shapes. In conclusion, subsets of neurons in V1 and V2 do code for the border ownership in natural scenes, however, the strength and accuracy of these early estimates of border ownership decreases with the complexity of the visual stimulus.

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34.25, *3:30 pm* **Brightness Illusions in a Neurophysiological Perspective**

Rüdiger von der Heydt[1](von.der.heydt@jhu.edu); [1]Mind/Brain Institute, Johns Hopkins University

The phenomena and theories of brightness illusions are a fascinating field of vision research. Neurophysiology has left little footprint in this field besides the lateral inhibition concept that did not fare so well. The purpose of this contribution is to point out a possible common neurophysiological explanation for a diverse sample of brightness and color illusions and emphasize the quest for a comprehensive theory. Single cell recordings have shown that neurons in the visual cortex emphasize luminance and color borders and generally signal their orientation. Many of these neurons (over 50% in area V2) are also selective for border ownership (Williford & von der Heydt: Scholarpedia 8(10):30040, 2013). Recent studies suggest that border ownership selectivity reflects grouping circuits in which neurons responding to the contours of an object activate grouping cells at higher levels which then, by feedback, enhance the responses of the same contour neurons. I argue that the activation of grouping circuits corresponds to the formation of proto-objects in cognitive theory. This process is parallel, fast and automatic. The activated grouping cells point to salient objects and provide handles for top-down attention and other object-based cognitive operations. Specifically, I propose here that lightness and color of objects are computed from the border signals in the corresponding proto-object representations. I will discuss how this theory can explain the phenomenon of filling-in (Krauskopf: JOSA 53, 741, 1963), the influence of image segmentation on color (Nakayama et al.: Perception 18, 55, 1989) and lightness perception (Anderson & Winawer: Nature 434, 79, 2005) and color after-images (van Lier etal. Curr. Biol. 19, R323, 2009), White's illusion (White: Perception 8, 413, 1979) and attention-induced brightness changes (Tse: Vision Res. 45, 1095, 2005). Some of these explanations are backed up by neurophysiological or psychophysical studies, but many questions await experimental answers.

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34.26, *3:45 pm* **Unexpected spatial sensitivity of neuronal response to illusory figures in area V4**

Michele Cox[1,2](Michele.A.Cox@vanderbilt.edu), Michael Schmid[1,3], Andrew Peters[1,4], Richard Saunders[1], David Leopold[1,5], Alexander Maier[1,2]; [1]Section on Cognitive Neurophysiology and Imaging, Laboratory of Neuropsychology, National Institute of Mental Health (NIMH), National Institutes of Health (NIH), Department of Health and Human Services, [2]Department of Psychology, College of Arts and Science, Vanderbilt University, [3]Ernst Strüngmann Institute for Neuroscience in Cooperation with Max Planck Society , [4]Neuroscience Graduate Program, University of California-San Diego, [5]Neurophysiology Imaging Facility, National Institute of Mental Health (NIMH), National Institute of Neurological Disorder and Stroke (NINDS), National Eye Institute (NEI), National Institutes of Health (NIH), Department of Health and Human Services

Illusory figures are a powerful demonstration of the visual system's ability to infer object boundaries and surfaces under conditions of fragmented sensory input. Neural correlates of illusory figures have been observed in a wide range of brain areas. Recordings in monkeys revealed that illusory figures evoke spiking responses from neurons in visual areas as early as V1 and V2 and as late as the inferotemporal cortex. Similarly, neuroimaging studies in humans identified responses to illusory figures throughout visual cortex. One area of particular interest is V4, as the receptive fields of its neurons are large enough to cover the separate stimulus elements and sensitive enough to distinguish between local features such as orientation, curvature, and colinearity. In order to investigate the role of mid-level visual area V4 in visual surface completion, we used extracellular multi-electrode arrays to measure spiking responses and low-frequency activity to two types of visual stimuli: Kanizsa patterns that induce the perception of an illusory surface and physically similar control stimuli that do not. Neurons in V4 exhibited stronger and sometimes rhythmic spiking responses for the illusion-promoting configurations compared to controls. Moreover, this elevated response depended on the precise alignment of the neuron's peak

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visual field sensitivity ("RF-focus") with the illusory surface itself. Neurons whose RF-focus over adjacent inducing elements did not show response enhancement to the illusion compared to the control stimuli. This spatial sensitivity suggests that, despite having large receptive fields, V4 neurons are able to draw upon spatially specific input, and that the observed response enhancement associated with the illusory surface may be computed before or within area V4. These finding will be discussed in relation to V4's functional domains as well as the putative role of rhythmic neural activity for the integration of feedforward and feedback signals in early visual cortex.

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34.27, *4:00 pm* **Bayesian Hierarchical Grouping: perceptual grouping as mixture estimation** Vicky Froyen[1](vickyf@rutgers.edu), Jacob Feldman[1], Manish Singh[1]; [1]Department of Psychology, Center for Cognitive Science, Rutgers University, New Brunswick, NJ, USA

We propose a novel Bayesian framework for perceptual grouping based on the idea of mixture models, called Bayesian Hierarchical Grouping (BHG). In BHG we assume that the observed configuration of visual elements was generated by a set of distinct mixture components ("objects"), each of which generates image elements stochastically under some probabilistic assumptions (which define an object class). Grouping, in this framework, means estimating the number and the parameters of the mixture components that generated the image, including estimating which image elements are "owned" by which components. BHG encompasses as special cases a number of classical perceptual grouping problems, including dot clustering, contour integration, and part decomposition. Moreover, unlike some competing models, BHG allows us to quantify the degree of belief for each competing grouping hypothesis. We present an algorithmic implementation of the framework, based on the hierarchical clustering approach of Heller & Gharamani (2005), illustrating it with examples drawn from each of the above problems. Although in principle there is an exponential number of competing grouping hypotheses, this framework allows a tractable approximation of the posterior. The output is an intuitive hierarchical representation of image elements, which gives an explicit decomposition of the image into mixture components, along with estimates of the probability of various candidate decompositions. Moreover the framework can generate predictive estimates of missing data, which provides intuitive predictions of amodally completed shapes. We show that the BHG accounts well for human grouping judgments, and gives good fits for our own human data as well as data drawn from the literature. Because BHG provides a principled quantification of the plausibility of grouping interpretations over a wide range of grouping problems, we argue that it provides an appealing, and unifying, formalization of the elusive Gestalt notion of Prägnanz.

Color and light: Receptors and mechanisms

Sunday, May 18, 5:15 - 7:15 pm
Talk Session, Talk Room 1
Moderator: Andrew Stockman

35.11, *5:15 pm* **Red-green flicker is encoded by a peak detector and limited by slew rate** Andrew Stockman[1](a.stockman@ucl.ac.uk), Caterina Ripamonti[1]; [1]Institute of Ophthalmology, University College London

The appearance of L- or M-cone rapid-on (slowly-off) or rapid-off (slowly-on) sawtooth modulated flicker depends on temporal frequency. At low frequencies (0.5-4 Hz), the flicker is seen as a red-green hue change that approximately follows the waveform. However, at higher frequencies (5-13 Hz) the hue change becomes asymmetric and there is a change in mean hue in the direction of the slow phase of the sawtooth—consistent with the hue mechanism being limited by a maximum rate of change (a "slew" rate limitation). To investigate these phenomena, we presented only the 1st and 2nd harmonics of the sawtooth flicker and varied the phase of the 2nd harmonic. The phase-dependent changes in red or green hue were assessed by separately matching them against the corresponding phase of square-wave flicker of the same fundamental frequency and of variable modulation. Both L- and M-cone flicker was used and the results were essentially the same. We find that the phase-dependent hue changes from 0.5-4 Hz are consistent with a red-green hue mechanism that signals the peak excursions of the composite waveform. Thus, the maximum excursion in hue towards red or green occurs when the peaks or troughs of the two harmonics align, rather than when the rate of change of hue is minimum. However, at higher frequencies this relationship breaks down, the rate of hue change becomes important, and the hue excursions often reach only intermediate red-green hues. Our results suggest that red-green hue appearance is mediated by a mechanism that encodes the peak excursions towards red or green, but one that is inherently limited in the rate at which it can signal changes in hue. This slew rate limitation becomes evident when the frequency (of the 2nd harmonic) exceeds about 8 Hz. Hue is not only low-pass filtered but also slew-rate limited.

Acknowledgement: BBSRC

35.12, *5:30 pm* **Temporal contrast sensitivity function based on cones and melanopsin photoreceptors** Sei-ichi Tsujimura[1](tsujimura@ibe.kagoshima-u.ac.jp), Naoshi Hamazono[1], Katsunori Okajima[2]; [1]Department of Information Science and Biomedical Engineering, Kagoshima University, 1-21-40, Koorimoto, Kagoshima 890-0065 Japan, [2]Faculty of Environment and Information Sciences, Yokohama National University, 79-7 Tokiwadai, Hodogaya, Yokohama 240-8501 Japan

Growing evidence indicates that the recently discovered the intrinsically photoreceptive retinal ganglion cells (ipRGCs) play an important functional role in conventional image-forming pathway as well as in non-image forming pathway, along with the classical photoreceptors rods and cones. Natural lights, therefore, stimulate rods, cones and ipRGCs, which convey visual information through image-forming pathway. However, the functional role of ipRGCs in the image-forming pathway is unclear. Here we show how stimulation of ipRGCs influences temporal contrast sensitivity function. A four-primary illumination system that enables independent stimulation of each photoreceptor class (Tsujimura et al., 2010, Proceedings of the Royal Society B-Biological Sciences, 277, 2485-2492) was used to present the following two types of test stimuli: one varying L-, M- and S-cone stimulation only without change in stimulation of ipRGCs (LMS cone stimulus) and another varying radiant flux of the stimuli without change in spectral composition which reduced/increased the radiant flux uniformly at all wavelengths (Light flux stimulus). The contrast threshold to temporally modulated sinusoidal gratings was measured. It was found that the two thresholds were different between LMS cone stimulus and the Light flux stimulus: the threshold to the LMS cone stimulus and the threshold to the Light flux stimulus became distinct at low temporal frequencies below 5 Hz. On the other hand, the thresholds at high temporal frequency were almost identical between the two stimuli. The difference in threshold at the low temporal frequency can be attributed to the difference in stimulation with or without ipRGCs, suggesting that ipRGCs play an important role in achromatic vision at low temporal frequency.

Acknowledgement: the Ministry of Education, Science, Sports, and Culture of Japan, KAKENHI (24657177 to S.T.)

35.13, *5:45 pm* **Melanopsin-driven responses in the human brain** Manuel Spitschan[1](mspits@sas.upenn.edu), Long Luu[1], Ritobrato Datta[2], David H Brainard[1], Geoffrey K Aguirre[2]; [1]Department of Psychology, University of Pennsylvania, [2]Department of Neurology, University of Pennsylvania

Photopic vision arises from three classes of cones (L, M and S) as well as from the recently discovered intrinsically photosensitive retinal ganglion cells (ipRGCs), which contain melanopsin. Much is known about the brain targets of signals originating from cones. Considerably less is known about the projections of the ipRGCs, particularly in the human brain. Here we use BOLD fMRI to measure neural responses in humans to spectral modulations that selectively target melanopsin while minimizing the responses of the cones, and compare these to responses generated using cone-targeted spectral modulations. Four observers viewed large-field (27.5° diameter, central 5° obscured) sinusoidal flicker (1-16 Hz, log spaced) at 470 cd/m2 during BOLD fMRI. Using the method of silent substitution and a digital light synthesizer, spectral modulations were directed at melanopsin, L+M, L-M, or S cones; an isochromatic modulation was also studied. Estimates of photopigment spectral sensitivities used to produce modulations accounted for observer age and stimulus size. Anatomical regions of interest were defined for the lateral geniculate nucleus (LGN; using volumetric templates), for primary visual cortex (V1) and for extrastriate areas (V2, V3 and hV4) (Benson VSS2012). Cortical voxels were restricted to >5° eccentricity as an extra precaution against contamination from changes in spectral sensitivity at the fovea. There was a robust melanopsin-driven response in both LGN and V1-hV4. In LGN, the melanopsin response was bandpass, maximal at 8 Hz with no measur-

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able response below 2 Hz. The melanopsin response in V1 and V2 through hV4 was also bandpass. Across areas the responses to cone-directed stimuli differed with the direction of the spectral modulation, and differed as well from the melanopsin-driven responses. Importantly, S-cone responses were distinct from melanopsin responses in both LGN and cortex.
Acknowledgement: R01 EY10016, R01 EY020516, P30 EY001583

35.14, *6:00 pm* **Visual Cortical Activity Evoked by Unconscious Chromatic Flicker** Xiuling Zhang[1,2](xiulingzhang01@gmail.com), Yi Jiang[3]; [1] School of Psychology, Northeast Normal University, Changchun 130024, P.R.China, [2]Department of Psychology, University of Maryland, College Park, MD, 20740, US, [3]Institute of Psychology, Chinese Academy of Sciences, Beijing 100101, P. R. China

Introduction When two isoluminant colors alternate at fusion frequency (25 Hz) or higher, observers perceive only one fused color. Recent fMRI research shows that many human visual cortical areas can distinguish between fused chromatic flicker and its matched nonflickering control. Here we use ERP method to investigate the C1 component evoked by fused chromatic flicker and its static control. Methods Sixteen people participated in the study. We used 2(color: fused chromatic flicker vs. static control) ×2 (visual field: upper left vs. lower right) within subject design. The fused chromatic flicker is two isoluminant colors (red and green) alternating at frequency of 30 Hz. The nonflickering control color is luminance matched static yellow. Each trial started with a fixation for 800-1200ms, then the color stimuli presented for 100ms. Participants were required to respond to the occasional size change of a central fixation. Results Our results showed that the C1 was affected by the invisible stimuli with increased amplitude to fused chromatic flicker than to its static control. At PZ, POZ, OZ, fused color evoked a higher peak amplitude C1 for both upper left ($F(1, 15) = 12.32$, $p<0.005$) and lower right visual field ($F(1, 15) = 6.56$, $p<0.05$). There is no significant difference between the amplitude of both P1 and N1 component evoked by fused color and static color. A forced choice study show that participants could not discriminate the fused color and static control. Conclusion The results showed that primary visual cortex could distinguish between invisible fused chromatic flicker and its matched nonflickering control suggesting that a considerable difference in visual cortical activation does not necessarily lead to different conscious experiences.

35.15, *6:15 pm* **Task-dependent neural population dynamics in sensory cortex** Satohiro Tajima[1](satohiro.tajima@riken.jp), Kowa Koida[2], Chihiro I. Tajima[3], Kazuyuki Aihara[3], Hideyuki Suzuki[3], Hidehiko Komatsu[4]; [1]Brain Science Institute, RIKEN, [2]Electronics-Inspired Interdisciplinary Research Institute, Toyohashi University of Technology, [3]Graduate School of Information Science and Technology, The University of Tokyo, [4]National Institute of Physiological Science

What is the physiological basis of our adaptive perception and decision making? Recent studies suggest that the dynamic, task-dependent behaviors may be accounted by readout stage, rather than sensory encoding stages (Mante et al., 2013; Sasaki & Uka, 2009). However, from a computational viewpoint, dynamic modulation at the encoding stage can benefit the task performances when the encoding quality is confounded by its own system noise. Based on this idea, we questioned whether sensory cortex also show any adaptive dynamics, which depends on the task demands. We analyzed responses of color-selective neurons recorded in the macaque IT cortex, which change their activities depending on the task demands: discrimination or categorization (Koida & Komatsu, 2007). To clarify the functional meaning of the task-specific modulation, we focused on the stimulus representation at the level of neural population rather than at single neurons. We found that the task demands modulated the global pattern of activity distribution over the neural population. Importantly, the modulatory component had a stimulus-dependent dynamics after the stimulus presentation, suggesting that the modulation can be driven by the visual input, rather than static biases which is attributed to classical forms of attention. The pattern of dynamics was consistent with the categorical attraction, which is predicted by a recurrent network model that approximates the optimal probabilistic inference of stimulus dynamics based on a hidden-Markov model (Imai et al., 2011). Moreover, this modulatory effect was accompanied by selective increases in the task-relevant stimulus information conveyed by the neural population. The increases in encoding information indicates that the modulation of sensory representation is not a secondary effect, which simply echoes the dynamics in other area, but playing functional roles in the maximization of task-relevant encoding performances. These results suggest that the dynamic mechanism of task-dependent computation can include the sensory encoding stage.
Acknowledgement: JSPS KAKENHI (25135718, 20246026)

35.16, *6:30 pm* **Neuronal population decoding can account for perceptual lightness illusions** David H. Brainard[1](brainard@psych.upenn.edu), Douglas A. Ruff[2], Marlene R. Cohen[2]; [1]Department of Psychology, University of Pennsylvania, [2]Department of Neuroscience, University of Pittsburgh

The relationship between the intensity of the light reflected from an achromatic object and the perceived lightness of the object appears depends on visual context. It has been difficult to relate this complexity to the activity of individual neurons, because neurons respond in varied ways to stimulus intensity. Can a population decoding approach clarify the neural underpinnings of perceived lightness? We employed stimuli derived from Adelson's checker-shadow illusion, such that probe disks presented on checkerboard images were seen to lie either within a shadowed region ('shadow' condition) or within a luminance-matched region without a shadow ('no shadow' condition). We evaluated whether similar changes in the lightness of the probe across the two conditions were revealed by human psychophysics and by lightness estimates obtained via decoding of the responses of several dozen cortical neurons in either area V4 or V1 of rhesus monkeys. Our psychophysical experiments confirmed and quantified the checker-shadow illusion for our stimuli: probes with the same intensity were perceived to be lighter in the 'shadow' condition than in the 'no shadow' condition. When we decoded the intensity of the probes using population responses of V4 neurons to the same stimuli, we found that the decoded intensities for the 'shadow' condition were consistently higher than those for the 'no shadow' condition. Moreover, there was a quantitative match between the psychophysical and V4 neural effects. In contrast, although probe intensity could be decoded from the population of V1 neurons as accurately as from the V4 neurons, the V1 decoding differences were not in agreement with the perceptual illusion. This result suggests that the checker-shadow illusion arises at least in part from cortical computations. More generally, our data support the notion that decoding the responses of neural populations can shed light on the neural correlates of complex perceptual phenomena.
Acknowledgement: RO1 EY10016 (DHB), R00EY020844 (MRC), R01EY022930 (MRC), T32NS07391 (DAR), Whitehall Foundation (MRC), Klingenstein Fund (MRC)

35.17, *6:45 pm* **Colour vision in 3D scenes: how much brain is needed to solve the Mach-card problem?** Annette Werner[1](annette.werner@uni-tuebingen.de); [1]Institute for Ophthalmic Research, Tuebingen University, Germany

Light fields in the real world are highly complex because they contain multiple illumination sources, including indirect light reflected from other surfaces. Such interreflexions are well compensated by the human visual system, by employing prior knowledge about the nature of the light field (Mach-card experiment: Bloj et al., 1999). Interreflections are the rule in natural environments and therefore a general problem for all organisms relying on colour vision, e.g. bees. Honeybees have excellent colour constancy as demonstrated for flat Mondrian-like scenes (Werner et al., 1988). However, bees have far fewer neurons available for these operations than humans and it is therefore interesting to ask: how can a complex colour vision task, like compensating the effect of light fields in 3D scenes, be solved by a relatively simple system? I will present a Mach-card experiment with free-flying honeybees (apis mellifera), where individual bees were trained to discriminate between green/white cards folded in different spatial configurations: (1) planar (2) concave and (3) convex. The stimuli (paper cards, 2.5 x 2.5 x 6 cm) were presented in front of a vertical, "grey" background (a turntable disc, 80 cm diameter). Previous experiments had shown that bees are able to resolve the depth profile of similar 3D forms. The results show that the bees recognized a trained green/white pattern irrespective of its spatial configuration, in other words, bees compensated the occurring interreflexions. Further experiments, involving simulations of the interreflexions, showed that the compensation depends on the consistency of spatial and chromatic cues. This suggests that bees use their knowledge about the spatial configuration in 3D scenes in order to discount the effects of mutual illuminations. Whether this involves cognitive inference, as it suggested for human colour vision, or is driven by hard-wired interconnections, remains to be solved.

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35.18, *7:00 pm* **Illumination Discrimination Reveals "Blue" Bias of Colour Constancy in Real and Simulated Scenes.** Bradley Pearce[1](b.m.pearce@ncl.ac.uk), Ana Radonjić[2], Hilary Dubin[2], Nicolas P. Cottaris[2], Michal Mackiewicz[3], Graham Finlayson[3], David H. Brainard[2], Anya Hurlbert[1]; [1]Institute of Neuroscience, Newcastle University, UK, [2]Department of Psychology, University of Pennsylvania, USA, [3]Computing Sciences, University of East Anglia, UK

Colour constancy stabilises object colours across a large variety of illumination and scene conditions in the natural world. It is unclear whether the neural mechanisms that mediate the phenomenon are optimised for the particular illuminations and surfaces to which we are typically exposed. Classically, colour constancy has been investigated by quantifying the change in appearance of test surfaces with large changes in illumination. Here we measure colour constancy by establishing discrimination thresholds for illumination changes, using a forced-choice paradigm. We compare performance for two different experimental setups: (1) a real, variegated-surface scene inside a viewing box, illuminated by spectrally tuneable multi-channel LED light sources (n=10 participants) and (2) a physics-based computer rendering of a similar scene, displayed stereoscopically on a pair of LCDs (n=9 different participants). For both setups, the illuminations (real or simulated) were metamers from the daylight chromaticity locus or atypical illuminations from an orthogonal locus. On each trial, participants viewed a target illumination (D67), then two subsequent illuminations, one the target illumination and the other a comparison whose chromaticity varied between 1–50 ΔEuv steps from the target. Discrimination thresholds were significantly higher (and therefore, colour constancy was better) for bluer illumination changes along the daylight locus, compared with greener illumination changes on the atypical locus, for both real and simulated scenes. Furthermore, we find no effect on discrimination thresholds of adding 3D objects to the scene, whether they are familiar or novel (fake hand, rendered spheres, painted blocks). Lastly, illumination discrimination thresholds for the real scenes were not significantly different from those for the simulated scenes. We conclude that when assessed via illumination discrimination and when using ΔEuv to parameterise illumination change, the mechanisms of colour constancy are biased for bluish daylight illuminations and that this bias may be measured robustly with real and simulated scenes.

Acknowledgement: EPSRC

Face perception: Neural mechanisms

Sunday, May 18, 5:15 - 7:15 pm
Talk Session, Talk Room 2
Moderator: Jessica Taubert

35.21, *5:15 pm* **Optogenetic and pharmacological suppression of face-selective neurons reveal their causal role in face discrimination behavior.** Arash Afraz[1](afraz@mit.edu), Edward S. Boyden[1], James J DiCarlo[1]; [1]MIT

Using optogenetic and pharmacological interventions we suppressed the activity of face-selective neurons in the inferior temporal (IT) cortex of macaque monkeys performing a facial gender discrimination task. Prior to behavioral testing, we determined the neural selectivity profile using a passive fixation paradigm and a large (~3x2mm) cluster of face-selective neurons was targeted for suppression. Adeno Associated Virus 8 was used to express ArchT at targeted location. Temporally-delimited (200 ms) optogenetic suppression of visually evoked activity at those locations was verified with custom made optrodes. The effect of optical suppression was compared with the effect of pharmacological silencing via muscimol microinjection at the same location. Both pharmacological and optogenetic suppression of these IT face-selective neurons produced a deficit in face discrimination. The deficit was specific to the contralateral visual hemifield, and it was not found for other locations in IT where the neuronal responses were not face selective. Specifically, optogenetic suppression of face neurons in randomly interleaved trials led to a significant drop in discrimination performance (median= 1.8%, mean=1.98%, t(17)=6.2, p<0.0001). Muscimol silencing of the same neurons caused a drop in discrimination performance (median= 4.9%, mean=5.53%, t(6)=3.98, p<0.01) 30 minutes after the injection, which persisted for the following 2 hours. The larger behavioral effect of muscimol-induced suppression is consistent with its larger spatial spread in cortex. Our results establish a causal link between the activity of some IT face-selective neurons and at least one type of face discrimination behavior. The demonstrated utility of optogenetic tools for inducing specific behavioral effects in a face discrimination task opens the door for applying the technical advantages of optogenetics to studies of high-level vision.

Acknowledgement: NIH K99 award for Arash Afraz

35.22, *5:30 pm* **Are the patches important? The effect of inversion on the responses of face-selective cells found throughout the monkey superior temporal sulcus.** Jessica Taubert[1,2](jessica.taubert@uclouvain.be), Goedele Van Belle[1], Wim Vanduffel[2,3,4], Rufin Vogels[2], Bruno Rossion[1]; [1]Institute of Research in Psychology and Institute of Neuroscience, University of Louvain, [2]Laboratorium voor Neuro- en Psychofysiologie, KU Leuven, Leuven, Belgium, [3]MGH Martinos Ctr., Charlestown, MA, USA, [4]Harvard Med. Sch., Boston, MA, USA

It is assumed that upright faces are processed by a set of functionally defined brain areas. In the monkey brain, face areas are comprised of a high proportion of face-selective cells, however, such cells can be found outside these fMRI defined face patches and throughout the Superior Temporal Sulcus (STS). It is not known whether the face-selective cells outside of the face patches behave the same way as the cells inside the face patches. In this study, we asked whether inversion has a differential effect on the responses of face-selective cells depending on anatomical position. We first localized, in two monkeys, several patches in STS that responded more to faces than other objects. Then, we recorded single units in two of these face patches (ML and AL) in addition to control positions between ML and AL. We searched for each cell using two categories of objects (faces and non-face objects) presented either in their canonical orientation or upside down. Face selectivity was defined using a Face-Selectivity Index (FSI = (mean responsefaces – mean responsenonface objects) / (mean responsefaces + mean responsenonface objects)). Face-selective cells that were recorded in ML responded more strongly to upright than inverted faces. The inversion of the preferred upright face had the same effect on the average response of the face-selective cells in the anterior face patch (AL). Additional recordings indicated that these effects in ML and AL were independent of retinal position. For face-selective cells that were found outside the face patches there was only evidence of a FIE when the search stimuli were upright. These findings imply that, while inversion has an impact on face representations in fMRI identified face patches, the same is not necessarily true for representations built elsewhere in monkey STS.

35.23, *5:45 pm* **Functionally-defined white matter selectively predicts face- and place-processing performance** Jesse Gomez[1,2](gomezj@stanford.edu), Franco Pestilli[1], Golijeh Golarai[1], Nathan Witthoft[1], Alina Liberman[3], Jennifer Yoon[1], Kalanit Grill-Spector[1,2]; [1]Psychology Dept., Stanford University, [2]Neurosciences Dept., Stanford University School of Medicine, [3]Psychology Dept., University of California Berkeley

Functional connectivity within a cortical network is essential for computation and behavior. If successful processing results at least partly from connectivity, then anatomical variations in white matter interconnecting a network should correspond to behavioral differences across subjects. However, it is unknown if white matter properties associated with a category-specific network affect category-specific processing. Using fMRI and diffusion-weighted imaging in adults (n=9, ages 18-40), adolescents (n=11, ages 12-16), children (n=13, ages 8-11), and developmental prosopagnosic (face-blind) adults (n=7, ages 25-53), we employ a novel protocol combining measurements of white matter properties, functional selectivity, and behavior in the same subjects. We quantify what we call functionally-defined white matter (FDWM) by extracting fiber tracts that pass near either a face-selective region on the middle fusiform gyrus (mFus-faces) or a place-selective region on the collateral sulcus (CoS-places). We find that in typical adults, diffusion properties in FDWM voxels immediately adjacent to face- and place-selective cortex correlate with accuracy in face or place processing tasks, respectively. Compared to typical adults, this relationship between FDWM local to functional regions and behavior is strikingly atypical in adults with developmental prosopagnosia, suggesting that atypical development of this FDWM-behavior relationship may have perceptual consequences. Lastly, this link between white matter properties and category-processing appears to undergo a protracted development, showing a gradual increase in its strength from childhood, to adolescence, to adulthood. We argue that white matter associated with functional divisions in high-level visual cortex is behaviorally relevant and should be a major component of future research in diffusion-weighted imaging.

Acknowledgement: NIH 1 RO1 EY 02231801A1

35.24, *6:00 pm* **Structural and functional connectivity fingerprints for face, body, scene, and object perception** Zeynep Saygin[1](zsaygin@mit.edu), Nancy Kanwisher[1]; [1]McGovern Institute for Brain Research and Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology

A fundamental hypothesis in neuroscience is that connectivity mirrors function at a fine spatial grain across the cortex. Previous research supports this hypothesis for the human brain, by demonstrating that the degree of voxelwise face-selectivity in the fusiform gyrus of individual subjects can be predicted from that voxel's connections to the rest of the brain (its unique connectivity fingerprint), measured through diffusion-weighted imaging (DWI; Saygin et al. 2012). Here we asked whether resting-state functional connectivity (fcMRI) can also predict face-selectivity in the fusiform gyrus, and whether structural or functional connectivity fingerprints also predict other visual selectivities in multiple extrastriate cortices. We found that both fcMRI and DWI connectivity predicted face selectivity in the fusiform more accurately than did a group analysis of face selectivity from other subjects. Prediction accuracies from DWI connectivity were slightly but significantly better than predictions from fcMRI connectivity for the fusiform gyrus. A direct comparison of the subset of connections that best predicted face-selectivity revealed that DWI and fcMRI connectivity fingerprints for function were generally quite similar, especially for the top predictors, although differences existed among weaker predictors. We performed similar comparisons of DWI and fcMRI connectivity fingerprints for other extrastriate regions and for body, object, and scene perception. These data provide converging evidence from both DWI and fcMRI that i) connectivity and function are tightly linked at a voxelwise scale in extrastriate cortex in humans, and ii) functionally-selective voxels can be predicted from either diffusion or resting functional data alone. These results also raise the possibility that connectivity fingerprints direct the functional specialization of cortex in development. Finally, this work has practical relevance for researchers and clinicians, by providing a method to infer functional brain maps from structural images alone in individuals who cannot be functionally scanned (e.g. comatose subjects, or sleeping infants).

Acknowledgement: MINT fellowship, Ellison Medical foundation

35.25, *6:15 pm* **Facial identity – an investigation of neural encoding and image reconstruction** Adrian Nestor[1](anestor@utsc.utoronto.ca), David Plaut[2,3], Marlene Behrmann[2,3]; [1]Department of Psychology at Scarborough, University of Toronto, [2]Department of Psychology, Carnegie Mellon University, [3]Center for the Neural Basis of Cognition, Carnegie Mellon University

Although recent research has mapped a network of cortical regions supporting neural representations of facial identity, the nature of the neural code within these regions is largely unknown. Here, we combine neuroimaging (fMRI) and computational investigations to address this issue, both in human adults with normal recognition abilities and in individuals with congenital prosopagnosia (CP). First, we employ multivariate mapping to localize ventral regions able to support individual face discrimination. Then, we use a computational model of face encoding based on independent component analysis, along with high-dimensional regularized regression, to estimate the neural patterns elicited by different faces within these regions. And last, we reverse this procedure in order to reconstruct facial images from relevant patterns of neural activation. Our results show that BOLD patterns related to face processing can be estimated fairly well, particularly in a region of the anterior fusiform gyrus. Moreover, this region is shown to support above-chance facial image reconstruction. Specifically, our assessment of neural-based image reconstructions shows that they are able to support above-chance identity recognition across variation in emotional expression. These results, in participants with normal recognition, also carry over—albeit to a more limited extent—to CP participants. The present findings shed light on the nature of high-level visual representations involved in face processing. At the same time, they also open up the possibility of a broad range of applications based on facial image reconstruction.

35.26, *6:30 pm* **Removing the right inferior occipital gyrus does not disrupt face-selective responses in human ventral temporal cortex: Evidence against a strict hierarchical model of face perception** Kevin Weiner[1](kweiner@stanford.edu), Louis Maillard[2], Jacques Jonas[2,3], Gabriela Hossu[4], Hélène Brissart[2], Corentin Jacques[3], David Loftus[1], Kalanit Grill-Spector[1,5], Bruno Rossion[3]; [1]Department of Psychology, Stanford University, Stanford, CA 94305, [2]Neurology Unit, University Hospital, Nancy, France, [3]Institute of Psychology, Institute of Neuroscience, University of Louvain, [4]Centre d'Investigation Clinique-Innovation Technologique, University Hospital of Nancy, Nancy, France, [5]Neuroscience Institute, Stanford University, Stanford, CA 94305

Neurofunctional models of face perception consider the "occipital face area" (IOG-faces/OFA) the input node to a hierarchy of face processing regions. It is presently unknown how removing this node affects downstream face-selective regions and the functional organization of human ventral temporal cortex (VTC) more generally. Here, we report a series of investigations using functional magnetic resonance imaging (fMRI) and intracerebral recordings with depth electrodes (sEEG) in a rare patient with intractable epilepsy. Behaviorally, the patient performed well above chance level at face perception and recognition tests although she performed significantly lower than normal controls. Pre-resection, a block design fMRI experiment using images of faces, body parts, places, and objects, showed a typical topology of functional regions in VTC (Figure 1). SEEG recordings revealed the highest face-selective response in the high gamma frequency range from 150 ms post-stimulus onset in an electrode located in the posterior fusiform face area (pFus-faces/FFA-1), indicative of normal latency of face selectivity. The resection included all of IOG-faces/OFA and the posterior aspect of pFus-faces/FFA-1. However, the right calcarine sulcus was intact and the patient did not suffer from a left visual field hemianopsia. fMRI conducted a month post-resection revealed that the topology and selectivity of face-, body part-, and place-selective regions anterior to the resection were preserved. Quantifying the topology of face-selective responses with multivoxel pattern analyses in VTC revealed that the correlation between pre- and post-resection scanning sessions was highly significant ($r=.62\pm.04$; $p<10-3$) and comparable to the correlation between two pre-resection scanning sessions ($r=.51\pm.05$; $p<10-3$), indicating the stability of face-selective responses post-resection. Interestingly, the patient's face perception and recognition remained stable after resection while her response times decreased two-fold. Altogether, these observations pose important constraints on the hierarchical neurofunctional model of face-selective responses in the human brain.

Acknowledgement: NIH 1 RO1 EY 02231801A1, ERC grant (facessvep 284025), Belgian National Fund for Scientific Research (FNRS)

35.27, *6:45 pm* **Human facial preferences are changed at the mercy of decoded fMRI neurofeedback** Kazuhisa Shibata[1,2](kazuhisa_shibata@brown.edu), Yuka Sasaki[1,2], Mitsuo Kawato[2], Takeo Watanabe[1,2]; [1]Department of Cognitive, Linguistics, & Psychological Science, Brown University, [2]Brain Information Communication Research Laboratory Group, Advanced Research Institute International

Preference to faces results from such complex processing that the conventional analyses that establish correlations between neural responses and behavioral measurements have not allowed us to completely understand the processing. Here, we tested whether any causal relationship can be established between activation in a specific area and changes in facial preferences. We used a decoded fMRI neurofeedback (DecNef) method, which can change activation patterns in a target region without subjects' awareness of the purpose of the experiment (Shibata et al, 2011, Science). In particular, we changed activation patterns in the cingulate cortex (CC), which has been implicated in facial preferences. First, 24 subjects were asked to rate their subjective preference to 400 faces. Second, we constructed a decoder to decode preference ratings from the CC activation for each subject. Third, for 3 days the subjects were presented with faces while simultaneously being reinforced to shape their CC activation toward the activation pattern that had been involved with higher (n=12, higher-preference group) or lower (n=12, lower-preference group) preference ratings. Subjects were only asked to make the size of a subsequently presented solid disc (feedback signal to subjects) as large as possible. The size reflected the decoded preference ratings computed from the subjects' momentary CC activation. We did not inform the subjects of what the size represented. Finally, subjects' preference ratings to the same 400 faces were measured again. As a result, the faces became significantly more preferred in the higher-preference group and less preferred in the lower-preference group. Further offline analysis indicated that CC activation during the DecNef training was predominantly contributed by CC itself, but not influenced by any other cortical areas. These results indicate that CC activation changes by the 3-day DecNef training without subjects' knowledge is causally linked to the modulation of human facial preference.

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35.28, *7:00 pm* **fMRI decoding reveals impaired face configuration representation in the right fusiform face area of individuals with developmental prosopagnosia** Jiedong Zhang[1](zhangjiedong@gmail.com), Jia Liu[2], Yaoda Xu[1]; [1]Department of Psychology, Harvard University, Cambridge, Massachusetts, USA, [2]State Key Laboratory of Cognitive Neuroscience and Learning, Beijing Normal University, Beijing, China

Developmental prosopagnosia (DP) refers to a lifelong face recognition deficit that cannot be attributed to acquired brain damage despite intact general cognitive abilities and sensory functions. Among the network of brain regions mediating face processing, the right fusiform face area (FFA) has been associated with face configuration representation. Paradoxically, DP individuals exhibit normal fMRI response amplitude profile in the right FFA, showing higher activation for faces than objects from other categories. This puzzling finding and other evidence have led to the conclusion that the right FFA appears to be intact in DP individuals but that connections among face processing regions are impaired. Using fMRI and multi-voxel pattern analysis (MVPA), here we report that DP individuals exhibited abnormal neural response patterns to faces in the right FFA. Specifically, the right FFA showed no discrimination between intact faces and faces in which parts were rearranged in a scrambled configuration (scrambled faces). This deficit was limited to the right FFA, as normal neural pattern discrimination for intact and scrambled faces was found in the right occipital face area and the lateral occipital object-processing region. DP individuals also exhibited normal face response amplitude profile and largely intact pattern discrimination to different face parts in the right FFA. Thus, in DP individuals, despite right FFA's preference to face stimuli and its ability to form unique representations for different face parts, face parts do not seem to be properly combined to give rise to the intact face gestalt to allow the formation of unique representations for intact and scrambled faces. To our knowledge, this is the first direct neural evidence showing that, in DP individuals, face configuration representation is impaired in the right FFA. We argue that such impairment may play a central role in behavioral deficits observed in DP individuals.

Acknowledgement: This research was supported by NSF grant 0855112 to Y.X, and National Natural Science Foundation of China grant 31230031 to J.L.

Sunday Afternoon Posters

Attention: Inattentional blindness

Sunday, May 18, 2:45 - 6:45 pm
Poster Session, Jacaranda Hall

36.301 **Perceptual Cycles in Complex Scene Perception:** Effects of Attentional Set on Detecting Events Thomas Sanocki[1](sanocki@usf.edu); [1]Psychology, U. of South Florida

A fundamental question remains open: How "constructed" is everyday perception in complex scenes? Evidence supports opposing views, while implicating interaction between bottom-up and top-down perception. Neisser's (1976) perceptual cycles framework integrates the opposing views, while positing a critical role for top-down schemata over time: Once activated (often by stimulation), a schema (or attentional set) determines which stimuli are most likely to be perceived. Little research tests this idea directly, beyond inattention studies where (e.g.) a gorilla is missed once. Here, we measure the power of an active schema to inhibit continuing conscious perception of known, visible, repeated, object-based events. Observers first learned the search tasks and the animated object-events (distractor events and color- or motion- feature target events), demonstrating 100% accuracy during training. Testing then began, with multiple objects alive contemporaneously, forming a continuous event stream; performance asymptoted at 80%. A schema (set) was activated by presenting only one target type for 2 blocks of trials. The schema was predicted to cause efficient perception of that event type ("set targets"), but not the other event type ("other targets"). The other targets were added in the next, critical block but (Experiment 1) only in outer regions, away from central attention. Accuracy remained high for the set targets, but was drastically lower for other targets (48% lower hit rate), consistent with predictions. When the other targets were added in the critical block at the center of attention (Experiment 2), performance dropped drastically for all target types (46% lower), implying set needed to be changed. Performance gradually returned to asymptote over 2 blocks in both experiments, as set was re-instantiated. These are strong schema effects on conscious perception, with object-events that are known, practiced, repeated, and highly visible.

36.302 **Appropriately Colored Scenes Reduce Inattentional Blindness** Kelly Webster[1,2](websterk3@gmail.com), Jason Clarke[3], Arien Mack[3], Tony Ro[1,2]; [1]Department of Psychology, The City College of the City University of New York, [2]Department of Psychology, The Graduate Center of the City University of New York, [3]Department of Psychology, New School for Social Research

Although several factors (e.g., unexpectedness, meaningfulness, and location) are known to influence inattentional blindness (IB), the role of color and scene gist has not been thoroughly examined. The Mack and Rock (1998) IB cross procedure was employed in three experiments to investigate the effects of color on IB. In the first experiment, subjects were tested on 90 trials, 60 of which contained different grayscale scenes and the remaining 30 a grayscale mosaic, all presented at fixation along with a cross in the periphery. On each trial, subjects were asked to report the longer arm of the cross and then responded as quickly as possible to whether a string of letters formed a non-word or a word; the word was either related or unrelated to the scene gist to measure priming. After the last trial, subjects were asked whether they were aware of anything on the screen aside from the cross and mosaic. Experiment 2 was identical to the first experiment except appropriately colored scenes instead of grayscale ones and colored mosaics were used, whereas Experiment 3 used color-negative versions of the colored scenes. Significantly fewer subjects (22%) reported being unaware of the scenes when they were appropriately colored as compared to when the scenes were grayscale (45%) or color-negatives (53%). Only subjects aware of the scenes showed evidence of gist priming, with positive priming for grayscale images, negative priming for appropriately colored images, likely because more inhibition of the scenes was required to suppress them from interfering with the main cross judgment task, and no priming for color-negative scenes, probably because they were difficult to decipher. Together, these results show that appropriate color information in a scene reduces IB, may be difficult to ignore, and facilitates conscious scene gist perception.

36.303 **Insensitivity to changes in spatiotemporal continuity when watching video** Joseph Schmidt[1,2](schmidtjoseph1@gmail.com), Jennifer Olejarczyk[1,2], Steven G. Luke[3], William J. Brixius[1,2], John M. Henderson[1,2]; [1]Institute for Mind and Brain, University of South Carolina, [2]Department of Psychology, University of South Carolina, [3]Department of Psychology, Brigham Young University

In real-world environments, stimuli move and change over time, yet most change detection studies use still-frame images. How is change detection modulated by the amount and direction of changes in spatiotemporal continuity when watching real-world videos, relative to the identical changes in still-frame images? In Experiment 1, observers were instructed to detect changes within continuous video clips. During critical saccades, videos shifted forward or backward in time by 0ms, 500ms, or 1000ms. Experiment 2 replicated the identical stimulus changes and removed motion percepts by exchanging the video stimuli with the still-frame images immediately before and after each change executed in Experiment 1. Detection accuracy with videos was surprisingly low (54%-68%), and significantly lower than with still-frame images (70%-82%, $p<.001$), suggesting a greater insensitivity to spatiotemporal continuity changes in videos. Larger temporal changes were detected more accurately (both experiments $p<.001$). Also, both experiments showed trends towards less accurate detection of forward relative to backward changes (significant when collapsed across experiments, $p<.02$), suggesting that predictive motion may mask some changes. Detection was also modulated by oculomotor properties; detection in videos was worse when observers were in stable fixation immediately after the change rather than in smooth pursuit (47%-76%, $p<.001$), despite all changes occurring during saccade rather than pursuit. Moreover, changes associated with stable fixation in videos were again detected less accurately in Experiment 2 (70%-85%, $p<.001$), where still-frame images were presented. This suggests a stimulus-based contribution to the stable fixation disadvantage in videos, as pursuit fixations could not occur with still images. However, the stable fixation disadvantage was larger in videos ($p<.001$), suggesting that the oculomotor act of pursuit itself may also improve detection. Collectively, the results suggest that forward and backward spatiotemporal continuity changes in videos are strikingly difficult to detect even when compared to the identical changes in still images.

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36.304 **Perceptual bottleneck of numerical proportion discrimination** Aire Raidvee[1,2](aire.raidvee@epfl.ch), Jüri Allik[1,3]; [1]Department of Psychology and Estonian Centre of Behavioural and Health Sciences, University of Tartu, Estonia, [2]Laboratory of Psychophysics, Brain Mind Institute, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland, [3]Estonian Academy of Sciences, Tallinn, Estonia

Observers were shown varying numbers of red and green dots randomly distributed in space. Observers indicated whether there were more green than red dots. Surprisingly, we found that only a small fraction of dots was taken into account for decision making. Similar results were found for oriented lines. Classically, such errors are explained by noise corrupting the neural representation of the dots. The idea that internal noise causes errors is at the very heart of Signal Detection Theory, and Thurstonian models in general. Here, we propose instead that errors occur because of undersampling rather than noise, i.e., observers choose only a small fraction of dots for decision-making, and the undersampling rate determines the error rate. This scenario can be best described by classical Bernoulli urn models. Our results are similar to attentional blindness, where salient objects often go unnoticed, such as a gorilla in a basketball game. Here we showed that this can also occur in processing of elementary features, such as dots or lines. Our results open a fundamentally new view on visual perception and decision making.

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See page 3 for Abstract Numbering System

36.305 Get ready and don't move your eyes: Investigating configuration and identity change detection in right and left visual fields.

Bonnie Angelone, Ph.D.[1](angelone@rowan.edu), Jessica Marcoux[1], Kelly Boland[1]; [1]Rowan University, Department of Psychology

For much of our everyday activity, the two hemispheres of the brain work together; however, previous research in lateralization of the hemispheres has shown they are also specialized for different tasks. Historical work has typically focused on the dichotomy between left and right hemispheres with respect to linguistic abilities. Still, other research suggests a visual information-processing dichotomy in that the left hemisphere is superior at processing categorical visual information and the right hemisphere is specialized for processing spatial visual information. In addition, when using Navon figures (larger letters composed of smaller letters), performance for the global information was better when presented to the right hemisphere while performance for the local information was better when presented to the left hemisphere. In two experiments, we examined a possible right and left hemisphere difference in change detection performance. In Experiment 1, observers attempted to detect a change to an array of three shapes presented to either the left or right visual field. The change (that occurred on some of the trials) was either the same array with three new shapes (identity change) or an array of the same shapes in three different positions (configuration change). Reaction time was faster for presentation to the right hemisphere for both types of change, while accuracy was better for identity changes overall. To account for participant predictions, in Experiment 2, observers viewed stimuli on both sides and had to decide if the change occurred in the right or left side. For reaction time, there was a significant interaction between change type and hemisphere; identity changes were detected faster when processed by the left hemisphere, but this also occurred in the right hemisphere, albeit not to the same degree. Taken together, these experiments partially suggest differences in right and left hemisphere processing of different types of changes.

36.306 Neural correlates of trans-saccadic change detection and change blindness in response to global contrast changes

William J. Brixius[1,2](wjbrixius@gmail.com), Joseph Schmidt[1,2], Steven G. Luke[4], Chris Rorden[2,3], John M. Henderson[1,2]; [1]Institute for Mind and Brain, University of South Carolina, [2]Department of Psychology, University of South Carolina, [3]McCausland Center for Brain Imaging, University of South Carolina, [4]Department of Psychology, Brigham Young University

Despite the importance of noticing visual changes, behavioral evidence shows that large changes often go undetected if they occur during visual field interruption, a phenomenon known as change blindness. Although a significant amount of behavioral research has investigated this topic, there is far less neuroimaging work and none using a saccade-contingent display change. This study utilized concurrent eye-tracking and fMRI to investigate the neural correlates of saccade-contingent global contrast change detection/blindness when viewing real-world photographs. Participants indicated whether they perceived a change after each trial. Two-thirds of trials were change trials and a staircase method was used to adjust the degree of contrast change to achieve approximately 50% detection. The change detection contrast (hit > miss) identified a well-defined, largely bilateral activation network (all $t>6.45$, $p<.05$ FWE) ranging from base feature detectors in the visual areas (cerebellum, V2, V3V) to ventral and dorsal processing stream activations and parietal attention-related areas (fusiform and lingual gyri, cuneus, putamen, insula, postcentral gyrus, intraparietal sulcus, inferior parietal lobule) to frontal/visuo-motor region activity (inferior and superior frontal gyri, supplementary eye fields), with marginally significant right-lateralized dorsolateral prefrontal cortex (DLPFC) activity. These results extend previous findings by highlighting the importance of bilateral activity and suggest that prior findings of robust DLPFC activation may have partly been due to dual task requirements. The change blindness contrast (miss > correct-rejection) revealed clear activation (all $t>6.61$, $p<.05$ FWE) in bilateral cuneus and fusiform and lingual gyri, but a distinct lack of fronto-parietal activity. Overall, these findings suggest that a largely bilateral ventral and dorsal fronto-parietal network is necessary for awareness of change. Thus, change blindness occurs when fronto-parietal activation related to attention is absent, despite notable neural activation that suggests detection without awareness.

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36.307 Eccentricity Effects on Change Detection

Pooja Patel[1](pooja@knights.ucf.edu), Joanna Lewis[1], Mark Neider[1]; [1]Department of Psychology, University of Central Florida

Attention capture effects are generally attenuated as stimuli are presented further from fovea (Carrasco & Yeshurun, 1998). However, the nature of this effect has not been characterized across different types of stimulus changes. In the current study, we used a singleton array (solid black circles on a white background) to determine whether change detection varies as a function of stimulus onsets or offsets and sizes at several visual eccentricities (10º, 20º, and 30º) using a flicker paradigm. Participants responded via button-press whether they detected a change or not. It was hypothesized that as stimulus size increased, from 1º to 2.5º in increments of .5º, participants would respond faster to a change. It was also expected that responses to onsets would be significantly quicker than offsets. Trials with no change were included to measure response accuracy. There were significant main effects of change type and eccentricity (all $p <.001$); participants responded significantly faster to onset than to offset changes (~106ms) and as eccentricity increased, participants spent more time to respond to a change. A significant change type x eccentricity interaction ($p <.001$) indicated that participants took longer responding to onsets at 30º than at 10º, and this difference was greater in offset trials. Analysis of accuracy data revealed a main effect for change type ($p <.001$) such that participants detected onsets correctly more often than offsets. Our data suggest that the ability to detect changes in the environment not only degrades with distance from the fovea, but is sensitive to the type of change to be detected.

36.308 If you can see it, you spot it sooner: Peripheral change detection is correlated with performance on `Spot-The-Difference' puzzles

Lavanya Sharan[1,2](sharan@alum.mit.edu), Ruth Rosenholtz[1,2]; [1]CSAIL, MIT, [2]Dept. of Brain & Cognitive Sciences, MIT

It has been argued that detecting a change between two images requires focused attention to the changed location (Rensink et al., 1997). We examine an alternative explanation based on the limitations of peripheral vision. If a change is discriminable in the periphery, it should be easily detected. Conversely, if the change is not discriminable in the periphery, it should be hard to detect. We evaluate this hypothesis using a `Spot-The-Difference' paradigm (Gur & Hilgard, 1975; Brunel & Ninio, 1997; Scott-Brown et al., 2000), where the goal is to identify differences between two images presented side-by-side. We gathered a set of 41 `Spot-The-Difference' puzzles from the web, 25 of which were derived from real-world photographs and the rest from illustrations. These puzzles, or image pairs, contained between 1 to 25 differences each. In Experiment 1, observers (n=6) viewed these image pairs freely, and for each pair, they identified differences by clicking on the corresponding image regions using a mouse. Observers were able to identify most differences (78%), with some differences being consistently harder to find than others. In Experiment 2, observers (n=7) viewed image pairs that were modified to contain either no differences or a single difference that was Easy, Medium, or Hard to find as established by Experiment 1. Observers were not allowed to move their eyes, and for each image pair, they indicated the presence or absence of a difference between two cued peripheral image regions using key presses. The accuracy at detecting a difference peripherally was significantly higher for the Easy differences (70%) than for the Medium (60%) or Hard (55%) differences (chance = 50%). These results support the hypothesis that performance on change detection tasks is at least partially constrained by low-level peripheral discriminability.

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36.309 A Convergent Gradient Field Model of Visual Attention

Brad Wyble[1](bwyble@gmail.com), Mingxuan Tan[2]; [1]Psychology Department, Penn State University, [2]Psychology Department, Syracuse University

Visual attention is frequently described as a spotlight that focuses on one location, but the underlying neural mechanisms of such an attentional system are not well established. We have been developing a candidate architecture for an attentional control system that exhibits the tendency for attention to converge at one location, but is also consistent with findings of divided attention in specific cases, as well as the structural and neurophysiological properties of the human visual system. This convergent gradient field (CGF) model simulates paradigms in which attention converges sharply at one location to the detriment of other locations (e.g. attentional capture), but can also exhibit multiple, stable attractors, when the triggering cues appear simultaneously. The model provides a unifying explanation of several attention effects, including attentional capture, attentional cueing, and some aspects of the attentional blink. The model predicts that the first step in deploying attention is to reconstruct the location of a target that has been detected by the ventral visual stream. This process of localizing a

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target produces a transient burst of neural activity within an attention map that ends when attention has successfully locked-on to the target's location. This transient burst of neural activity may be the neural source of the N2pc component of the EEG. Accordingly, the model predicts that two sequential targets in the same location will produce an N2pc that is identical to that produced by a single target, which our experimental data have confirmed. The model also predicts that the offset of the N2pc marks the initiation of attentional selection within the visual field. This work places new constraints on our understanding of attention and suggests that the inhibitory connections that cause convergence of attention may have an important role in segmenting a continuous input into discrete packets of information.

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36.310 **Object substitution masking of symbolic stimuli and the allocation of spatial attention.** Eric Taylor[1](j.eric.t.taylor@gmail.com), Davood Gozli[1], Jay Pratt[1]; [1]University of Toronto

Symbolic cues, such as arrows or words, can affect the way we allocate attention in the visual field. In this project, we asked whether awareness of arrows and words would modulate this effect. In two experiments, we used object substitution masking to conceal arrows or words and measured their effect on the processing of spatial information. In the first experiment, participants performed a modified spatial Stroop task in which a word (ABOVE, BELOW, LEFT, or RIGHT) would appear inside a four-dot pattern at one of four locations above, below, left, or right of fixation. Participants had to identify the word, as quickly as possible, regardless of location. The four-dot pattern could offset simultaneously with the word (unmasked condition) or delayed by 200ms (masked condition). We found a typical compatibility effect between the word identity and location when the word reached awareness and a negative compatibility effect when the word was successfully masked. A second experiment, used similar procedures except that an arrow (pointing left or right) was presented within a four-dot pattern either above or below fixation. Participants made a speeded response to the onset of a target on the left or right of the screen. As before, the four-dot pattern could offset simultaneously with the arrow (unmasked) or 200ms later (masked). We found that compatible arrow cues facilitated target detection in the unmasked condition, but this pattern reversed in the masked condition where target detection was slower with compatible arrow cues. These findings indicate that the effect of symbolic cues depends on awareness, and that symbolic cues presented below awareness can produce negative compatibility effects.

Attention: Neural mechanisms

Sunday, May 18, 2:45 - 6:45 pm
Poster Session, Jacaranda Hall

36.311 **The role of cortical and subcortical suppression in spatial attention.** André D Gouws[1](andre@ynic.york.ac.uk), Ivan Alvarez[1], David Watson[1], Maiko Uesaki[1], Jess Rodgers[1], Antony B Morland[1,2]; [1]York Neuroimaging Centre, Department of Psychology, University of York, York YO10 5DD, UK, [2]Centre for Neuroscience, Hull-York Medical School, York YO10 5DD, UK

The allocation of spatial attention results in enhanced perception at attended locations at the cost of perception at unattended locations. While functional MRI (fMRI) studies have shown that cortical representations of unattended visual locations can display negative BOLD responses, this 'suppression' remains poorly understood. We sought to characterise the suppression expressed in retinotopic representations of unattended locations asking the following questions. At what stages of the visual hierarchy is suppression expressed? What is the task- and stimulus contrast- dependence of suppression? Participants viewed a lateralised 120° sector of an annulus (inner radius 4°, outer 18°), equally divided by the horizontal meridian. Upper and lower halves of the stimulus were luminance contrast gratings (6%, 12%, 25% or 100%) drifting in opposite directions and reversing unpredictably. Each fMRI run comprised eight, 16s, grating blocks alternating with a 16s uniform field equiluminant to the grating. High resolution (1.5x1.5x2.4mm3) fMRI data we acquired (128 volumes, TR=2s, 8 cycles, 4 scans per contrast/task combination), while participants fixated a dynamic central target and counted either the number of grating reversals (stimulus-related task) or the number of targets at fixation (central task). Separate functional and anatomical acquisitions were used to define V1, V5 and LGN regions of interest contralateral and ipsilateral to the stimulus in each participant. Repeated measures linear modelling analysis of positive BOLD responses revealed expected increasing attention-dependence but decreasing contrast-dependence moving up the visual hierarchy from the LGN to V5. In the representations of unattended locations of the LGN and V1, however, we observed suppression, which was highly task dependent but largely independent of the attended stimulus contrast. Whole brain analysis revealed that these suppressive effects were also found in the pulvinar, which has been frequently associated with attention. Suppression therefore, most notably in subcortical structures, plays an important role in spatial attention.

36.312 **Pre-Saccadic Modulation of the Visual Evoked Potential** Leslie Guadron[1](lguadro00@citymail.cuny.edu), Annabelle Blangero[1], Simon P. Kelly [1]; [1]Department of Biomedical Engineering, The City College of the City University of New York,

A long line of psychophysics studies has shown that subjects can discriminate stimuli presented at the location of an upcoming saccade better than at any other location. Whereas similar spatially-selective effects on performance due to covert top-down attention have been extensively studied using visual evoked potentials (VEPs), and have provided valuable insights into neural underpinnings, technical challenges hamper VEP measurements for presaccadic targets. Such an approach could illuminate distinctions between presaccadic attention and endogenous covert attention that have been hard to make using psychophysical paradigms. We have developed a paradigm that enables testing for modulation of early visual processing by saccade planning. Subjects make regularly-paced (but uncued) saccades every 800-ms between four targets continuously displayed on a screen in a diamond pattern. By having the subjects focus on their saccade timing, rather than on assessing some aspect of the visual target, we hoped to minimize the contribution of voluntary attention to eye movement planning. The spatial location of the targets were chosen to give rise to a maximal "C1," the earliest, striate-generated VEP component. Task-irrelevant Gabor patterns were presented at either the saccade goal or at the opposite location at various times prior to the next saccade onset. Extensive data have been collected from one subject and no spatially-selective modulation of visual processing (C1 and P1 amplitude) can be observed. In order to obtain a behavioral measure of the locus of attention, in a second experiment we asked subjects to report detection of luminance decrements within the Gabor probes. Despite exhibiting relatively better detection at the saccadic goal, there was still no VEP modulation. Critically, the same subject displays a modulation of her C1 by covert attention in the same contrast discrimination task with endogenous cues and no saccades.

36.313 **Spatial attention reduces correlated noise in the fMRI response** Wesley Chaney[1](wchaney07@gmail.com), Jason Fischer[2], Gerrit Maus[3], David Whitney[1,3,4]; [1]Vision Science Graduate Group, University of California, Berkeley, [2]Department of Brain and Cognitive Sciences and McGovern Institute for Brain Research, Massachusetts Institute of Technology, [3]Department of Psychology, University of California, Berkeley, [4]Helen Wills Neuroscience Institute, University of California, Berkeley

Spatial attention modulates sensory neural activity, enhancing the representation of relevant stimuli and leading to enhanced performance in a variety of tasks. However, the exact mechanisms by which attention modulates early sensory activity and how this impacts the fMRI BOLD response are not yet fully understood. Previous studies recording from single units in area V4 have demonstrated that attention reduces correlations in the noise of simultaneously observed neurons (Cohen and Maunsell, 2009; Mitchell et.al., 2009). We tested whether analogous reductions of correlated noise also occur at the population level using the fMRI BOLD signal. We examined the effects of attention on the representation of four Gabor stimuli presented simultaneously in each quadrant of the visual field at jittered eccentricities. Subjects attended for contrast decrements in the Gabors in one visual field (either upper or lower in alternating runs) while ignoring the Gabors in the other visual field. After regressing out stimulus driven activity in V1 and V2 in a General Linear Model analysis, we analyzed pairwise correlations of the residual timecourses in voxels representing either the attended or unattended visual fields. We found that attention to either the upper or lower visual field reduces both the correlation and coherence of these timecourses. This reduction is opposite to what would be predicted from reduced noise within individual voxels or an increase in stimulus driven activity due to attention and it cannot be explained by vasculature differences or local scanner artifact as each region is attended or ignored for an equal number of runs. This reduction in correlated noise within attended locations allows for more accurate signal estimation at the population level, and may facilitate readout by higher level processes that pool over information in early visual cortex.

36.314 **Remediation of abnormal visual motion processing significantly improves attention, reading fluency, and working memory in dyslexics** Teri Lawton[1,2](tlawton@pathtoreading.com), Jordan Conway[1], Steven Edland[3]; [1]Department of Computer Science and Engineering, UCSD, La Jolla, California 92093, [2]Perception Dynamics Institute, PO Box 2206, Del Mar, California 92014, [3]Department of Neurosciences and Division of Biostatistics and Bioinformatics, Department of Family and Preventive Medicine, UCSD, La Jolla, California 92093

Introduction. This study investigates the assumption that reading deficiencies are only phonologically-based by testing the relative efficacy of current visual and auditory timing interventions to treat dyslexia. Methods. We performed a randomized trial on 75 dyslexic second graders in six public elementary schools, comparing interventions targeting the temporal dynamics of either the auditory (FastForWord 30 minutes per day, five days per week), or visual (PATHtoReading 30 minutes per day, three days per week) pathways for 20 weeks, or a combination of auditory (for 10 weeks) and visual (for 10 weeks) interventions, with the school's regular reading intervention Learning Upgrade, (control group). Interventions were administered before guided reading, so students practiced reading after the timing interventions. Standardized tests of reading fluency, attention, and working memory were used to evaluate improvements in cognitive function. Changes in standardized scores before and after the intervention training were analyzed by ANCOVAs to compare treatment response across groups. Results. Most dyslexics in this study had significantly elevated contrast thresholds for movement discrimination when compared to those for typically-developing second-graders. Only visual movement-discrimination training to remediate abnormal visual motion processing significantly improved contrast thresholds for movement-discrimination, reading fluency (both speed and comprehension), phonological processing, attention, and both visual and auditory working memory. ANCOVAs found that most results were statistically highly significant. Auditory training to improve phonological processing did not significantly improve these skills in schools administering both auditory and visual interventions. Conclusions. The significant improvements in phonological processing and auditory working memory under the PATH regimen demonstrate that visual movement-discrimination training improves auditory skills even though it is designed to train visual skills. These results provide more evidence that visual motion processing is fundamental for learning to read and remediating reading and attention deficits, and argue against the assumption that reading deficiencies in dyslexia are only phonologically-based.

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36.315 **Nasal-temporal Asymmetries of the N2pc Component** Christoph Huber-Huber[1](christoph.huber-huber@univie.ac.at), Anna Grubert[2], Ulrich Ansorge[1], Martin Eimer[2]; [1]Department of Basic Psychological Research and Research Methods, University of Vienna, [2]Department of Psychological Sciences, Birkbeck College, University of London

Attentional capture is known to be modulated by the hemifield of stimulus presentation. Previous research has demonstrated stronger capture by stimuli in the temporal as compared to the nasal visual hemifield (Rafal, Henik, & Smith, 1991). We measured N2pc components as an index of attentional object selection in response to bilateral displays. Participants' task was to identify the digit in a pre-specified target color and to ignore the other nontarget-color digit. In different blocks, the right eye or the left eye was patched, so that the digit in the temporal visual hemifield was projected onto the nasal hemiretina and the nasal digit to the temporal hemiretina. As expected, N2pc components were elicited contralateral to the visual field where a target was presented. Critically, this component was attenuated and delayed for targets on the nasal hemiretina relative to targets that stimulated the temporal hemiretina. This result appears opposite to what would be expected if targets in the temporal visual field attract attention more efficiently, and suggests that the N2pc reflects the combined effects of attentional target selection and distractor suppression (Hickey, Di Lollo, & McDonald, 2009). Distractor suppression triggers a Pd component that is opposite in polarity to the target N2pc, and emerges during the same time interval. Distractor objects in the temporal visual field require stronger attentional suppression than nasal distractors, and therefore elicit larger Pd components, resulting in larger net N2pc components on trials where temporal distractors stimulated the nasal hemiretina and nasal targets were simultaneously projected onto the temporal hemiretina.

36.316 **Examining early spatial selection through a novel brightness illusion: Voluntary attention shapes the early selection of information.** Snigdha Banerjee[1,2](snigdha.banerjee@einstein.yu.edu), Hans-Peter Frey[2], Kristen Morie[2], Sophie Molholm[2], John Foxe[2]; [1]The Graduate Center of the City University of New York, [2]Albert Einstein College of Medicine

Introduction: Recent behavioral work showed that internal cognitive factors played a role in regulating brightness perception, suggesting that higher order regions may modulate early visual activations through early attentional selection. A recently developed visual illusion (Tse, Vision Research, 2005) provides a strong example of a circumstance under which spatial attention influences perceived brightness in a "consciously perceptible" and "voluntarily manipulable" manner, providing an excellent means to assess the neural mechanisms of early attentional selection. We predicted that early visual evoked potentials would be enhanced for attended stimuli in this study, which would provide a compelling neural correlate for early attentional selection. Methods: Twenty-eight neurologically typical participants were included in this study. High-density EEG and eye-tracking were recorded. In each trial, participants selected a circular surface in the illusion that they would covertly attend. Subsequently, a sinusoidal grating appeared in one of the circles, and participants responded whether or not they detected a target (white ring in the grating). Early visual components (C1 and P1) were analyzed using Field-Trip. Results: For d-prime, a main effect of attention ($p = .001$) and a stimulus location x attention interaction ($p = .005$) were found. For reaction times, a main effect of attention ($p = .000$) and a stimulus location x attention interaction ($p = .024$) were observed. For the EEG data, a main effect of attention was found for the C1, ($p = .047$), but only in upper stimulus locations. For the P1, main effects of stimulus location ($p = .000$) and attention ($p = .028$) were observed. Conclusions: These findings revealed that voluntary attention modulated behavior and early visual evoked potentials, and these effects differed based on the spatial location of stimuli. These results suggest that voluntary, self-directed attention influences the early selection of information in hierarchically early visual cortices.

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36.317 **Spatial priority- and content-based attentional filtering disassociated along a posterior to anterior axis in visual cortex** Johan D Carlin[1,2](johan.carlin@mrc-cbu.cam.ac.uk), Justin L Gardner[1]; [1]Laboratory for Human Systems Neuroscience, RIKEN Brain Science Institute, 2-1 Hirosawa, Wako, Saitama 351-0198, Japan, [2]Medical Research Council Cognition and Brain Sciences Unit, 15 Chaucer Road, Cambridge CB2 7EF, UK

Human observers easily prioritize processing of task-relevant stimuli in cluttered visual scenes. This study used fMRI to characterize how effectively regions across human visual cortex filter a target's spatial location or content from task-irrelevant distractors. Nine subjects performed a task that involved following spatial cues to attend content (faces or houses, 9 degrees visual angle in diameter) in one of two parallel stimulus streams (5.1 degrees above or below fixation) in 16.2s blocks. We used cross-classifiers to obtain separate readouts of content-tolerant spatial priority representations and spatially-tolerant content representations. To isolate the efficacy of top-down attentional filtering from other factors that influence absolute classification accuracy we defined a filtering efficacy metric as the ratio of classification when the distractor stream was present compared to absent. Thus, filtering efficacy is 1 when classification performance is unaffected by the distractor and 0 if the distractor reduces classification to chance. Both dorsal and ventral visual stream regions were found to feature highly effective content filtering (efficacy>0.75 in V3a, TOS, ips0-2, hV4, OFA, PPA and FFA). Spatial filtering also was similar along a dorsal-ventral axis, but was maximally effective in mid-level visual cortex (efficacy>0.66 in V3, V3a and hV4). By contrast, the classic where-what division was evident in the profile of classification accuracy for bottom-up visual responses in the no distractor context, with most accurate spatial classification in dorsal regions and content classification in ventral regions. Our results suggest that spatial priority- and content-based filtering are distinct attentional mechanisms which are dissociated based on their efficacy profiles along a posterior-anterior axis. Thus, top-down filtering acts diffusely across both streams rather than following the organization of bottom-up response preferences into dorsal 'where' and ventral 'what' streams.

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36.318 **Attention-induced lateralization of EEG alpha-oscillations subserves a psychophysical contrast-gain effect.** Niko Busch[1,2](niko.busch@gmail.com); [1]Charité University Medicine Berlin, [2]Berlin School of Mind and Brain, Humboldt-University

The brain is never resting; spontaneous neuronal activity is ever-present even in the absence of external stimulation. How does this spontaneous brain activity interact with the processing of visual information? Spontaneous electrophysiological oscillations in the alpha frequency-band (8–12 Hz) just before stimulus onset have been shown to impair detection of an upcoming stimulus. Moreover, voluntary shifts of covert attention induce lateralization of alpha power: power increases in the cortical hemisphere ipsilateral to the attended location and decreases in the contralateral hemisphere, indicating suppression of distracting information in the unattended hemifield. In this study, we investigated the psychophysical mechanism underlying this effect in an orientation discrimination task using Gabor patches of different contrast levels in combination with an attentional cueing procedure. Compared to a neutral condition, attentional cueing improved discrimination of the Gabor targets, and this effect was best described by a contrast gain effect. Moreover, cueing induced the expected lateralization of alpha-band power in the time interval between cue and target onset when power was averaged across trials. However, the degree and direction of pre-target single-trial lateralization was highly variable across trials. On some trials, pre-target lateralization was even reversed, indicating attentional shifts directed away from the cued location. We found that this single-trial lateralization was predictive of task performance on cued trials: strong lateralization towards the cued location resulted in best performance. Modeling of the resulting psychometric functions revealed that this improvement was characterized by a contrast gain effect that paralleled the effect found in the comparison of cued vs. neutral trials. Thus, the psychophysical effect of attention-induced alpha-band lateralization is best described as a net increase in visual sensitivity, similar to an actual change in physical stimulus contrast.

36.319 **Attentional allocation locally warps representational space** Samuel A. Nastase[1](sam.nastase@gmail.com), Andrew C. Connolly[1], Nikolaas N. Oosterhof[1,2], Yaroslav O. Halchenko[1], Jason Gors[1], M. Ida Gobbini[1,3], James V. Haxby[1,2]; [1]Dept. of Psychological & Brain Sciences, Dartmouth College, Hanover, NH, USA, [2]Ctr. for Mind/Brain Sci. (CIMeC), Università degli Studi di Trento, Rovereto, Italy, [3]Dept. di Psicologia, Università di Bologna, Bologna, Italy

Attentional allocation is hypothesized to transiently and selectively warp representational space. In the current study, participants viewed brief video clips of five types of animals each performing four actions. In each run, participants performed a 1-back task requiring them to attend to either the animal type or the action performed. Surface-based searchlight SVM classification revealed distinct areas coding for animal category and action category. Action classification was greatest in lateral occipital, superior parietal and postcentral regions, while animal classification was greatest in early visual and ventral temporal cortices. Classification accuracy increased with attention in higher-level cortical areas thought to code for category-level animal and action information, while accuracy in early visual areas decreased with attention. A representational similarity multiple regression analysis implemented with surface-based searchlights revealed that target similarity structures are differentially predictive of the neural similarity structure as a function of attentional task. These results suggest that attention warps distributed representational spaces such that task-relevant representations are more discriminable. Furthermore, cortical areas corresponding to early and late visual processing are differentially impacted by this attentional warping effect.

36.320 **Sensory and response interference is resolved locally** Jack Grinband[1](jg2269@columbia.edu), Tobias Teichert[2], Vincent Ferrera[3], Joy Hirsch[4]; [1]Department of Radiology, Columbia University, [2]Department of Psychiatry, University of Pittsburgh, [3]Department of Neuroscience, Columbia University, [4]Department of Neurobiology, Yale University

Current models of cognitive control have argued that the frontal cortex dynamically allocates attentional resources during perceptual decisions. Specifically, momentary changes in sensory or response interference may result in top-down modulations of sensory input. To test this hypothesis, we performed fMRI using a visual motion interference task in which two sets of black and white moving dots were simultaneously presented. Human subjects made simple decisions about the direction of motion of the target dots while ignoring the distractor dots. In this task, reaction time increased with the amount of sensory interference whereas error rate increased with the amount of response interference. These behavioral differences allowed us to psychophysically dissociate these two types of interference. We found neural activity modulated by the amount of sensory interference only in sensory cortex (area MT+/V5), whereas activity modulated by the amount of response interference was located only in frontal cortex (supplementary motor cortex). Furthermore, functional connectivity between sensory and frontal cortex during the decision was found to be close to zero. These data suggest that interference is minimized and resolved locally without engaging top-down feedback loops.

36.321 **Optimizing decision-making by delaying decision onset** Tobias Teichert[1,3](teichert@pitt.edu), Vincent Ferrera[1], Jack Grinband[2]; [1]Department of Neuroscience, Columbia University, [2]Department of Radiology, Columbia University, [3]Department of Psychiatry, University of Pittsburgh

Most decisions are based on stimuli that appear in the midst of task-irrelevant information. Thus, accurate decision-making critically depends on a selection process that directs attention to task-relevant stimuli, while suppressing irrelevant information. It is often assumed that subjects can increase response accuracy by gathering more evidence before responding. However, the fact that the engagement of selective attention takes time, suggests the possibility of an alternative or additional mechanism for increasing accuracy: subjects may delay decision onset until selective attention has isolated task-relevant information. To test this, human subjects performed a parametric variant of a Stroop-like interference task. In our dots-interference task subjects reported the direction of motion of a set of target dots while ignoring the direction of distractor dots that either moved in the same direction, the opposite direction or orthogonal to the target dots. In different sessions subjects emphasized either speed or accuracy. In addition, subjects performed the same task but were required to synchronize their responses to a timing cue (response signal). We used the response signal paradigm to infer the time course of selective attention in the dot-interference task using an extended version of the standard drift-diffusion model. Data from the response signal paradigm suggests that it takes subjects approximately 120 ms to isolate information from the target dots in a winner-take-all fashion. Based on the time-course of selective attention we modeled reaction time distributions and accuracy in the speed and the accuracy condition of the reaction time version of the same dots-interference task. These results show that decision onset is to some degree under cognitive control and that human subjects not only raise response threshold, but also delay decision onset by ~50 ms to trade speed for accuracy in a Stroop-like interference task.

36.322 **Load-Induced Visual Enhancement and Suppression Modulates with Attentional Field Size** Matthew Gannon[1](magannon@uark.edu), Dorothy Currey[1], Nathan Parks[1]; [1]University of Arkansas

Increasing the attentional demands (load) of a visual task leads to neural enhancement of task-relevant stimuli and suppression of irrelevant visual distractors. Here, we examined the spatial dynamics and malleability of such enhancement and suppression by manipulating attentional field size in a central load task and measuring visual evoked potentials (VEPs) across the visual field. Subjects performed an attentional load task in which they responded to visual targets that varied in color and orientation, updating every 1400 – 1550 ms. Assignment of visual targets alternated between blocks. In low-load blocks, visual targets were distinct in color from non-targets. In high-load blocks targets were discriminable from non-targets only by a identifying a conjunction between color and orientation. Attentional field size was also manipulated between blocks by scaling the size of stimuli in the load task between 1.0 and 2.5 degrees. While subjects performed the attentional load task, concentric checkerboard annuli were used to evoke cortical visual responses for five eccentricities across the visual field (0.5, 1.25, 4.0, 6.0, and 13.0 degrees). A randomly selected checkerboard annulus was contrast reversed every 300 – 650 ms. Separate VEPs were calculated for each level of attentional field size, attentional load, and annulus eccentricity. The early sensory components of these VEPs (P1 and N1) were assessed across the visual field for effects of attentional load and attentional field size. Manipulation of attentional field size resulted in robust differences in the distribution of attentional effects across the visual field (as indexed by P1 and N1) such that a smaller attentional field led to discrete attentional modulations of visual responses (enhancement and suppression) across the tested eccentricities whereas a larger attentional field induced broader and less well-defined attentional effects across space.

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36.323 **Impaired saliency suppression in old age: left IPS' indifference lets extrastriate cortex run wild** Carmel Mevorach[1](c.mevorach@bham.ac.uk), Lilach Shalevl[2]; [1]School of Psychology, The University of Birmingham, UK, [2]The Constantiner School of Education and the Sagol School of Neuroscience, Tel-Aviv University, Tel Aviv, Israel

Top-down attention selection may involve both target enhancement and distractor suppression. These mechanisms, however, appear to be differentially affected in ageing. In particular it has been argued that distractor suppression is impaired as we age (Gazzaley et al., 2005). In accordance with this concept we have previously shown (Tsevetanov et al., 2013) that older participants are particularly impaired at ignoring salient distracters when instructed to respond to low salient targets. We have also shown that in young adults this function relies on a parieto-occipital circuit whereby left IPS down-regulates cortical responses to salient distracters in visual cortex (Mevorach et al., 2010). Here we investigate the underlying brain circuitry that accompanies reduced salience-suppression in old age by inspecting the brain network typically involved in such top-down selection. We used fMRI with old and young adults who were asked to identify either the global or the local aspect of a hierarchical letter under conditions where the target or the distractor level is more salient. Behaviourally, old adults showed increased susceptibility to salient distracters on both the global and local levels. Furthermore, left IPS recruitment in distractor-salient conditions was absent in the older group. At the same time there was also evidence that in old (but not in young) participants specialised extrastriate visual cortex regions are driven primarily by the bottom-up saliency of the global and local information. The data suggest that impaired top-down attention in old age is associated with an indifferent attention control which in turn lets the visual representation be dominated by bottom-up saliency. An open question remains as to whether this is the manifestation of impairment in the top-down mechanism or rather simply a change in strategy where suppression is not called upon (but is not otherwise impaired).

36.324 **Top-down attention modulates representational stability in the medial temporal lobe** Mariam Aly[1](aly@princeton.edu), Nicholas B. Turk-Browne[1,2]; [1]Princeton Neuroscience Institute, Princeton University, [2]Department of Psychology, Princeton University

Attention broadly enhances cognition, including perception and memory. The enhancement of perception has been linked to modulation of visual areas that code for attended locations or features. How attention enhances memory, however, is not known. The effect of attention on memory may be a downstream consequence of its effect on perception, with better visual representations more amenable to encoding. Alternatively, attention may also modulate brain areas that subserve memory encoding, including regions in the medial temporal lobe (MTL). To examine this latter possibility, we conducted a high-resolution fMRI study in which we manipulated attention in a novel "art gallery" task designed to draw heavily on the MTL. On each trial, participants were first presented with a target room containing a painting. They then viewed four more rooms and searched for either the same room layout from a different perspective (room state) or a painting from the same artist (art state). Critically, the same trials were completed in both tasks, controlling the physical stimuli and allowing top-down attentional states to be identified. In univariate analyses, the perirhinal cortex and hippocampus were more strongly activated by art attention, while the entorhinal and parahippocampal cortices were more strongly activated by room attention. Multivariate analyses revealed greater pattern similarity for same (art/art and room/room) compared to different (art/room) attentional states in all hippocampal subfields and MTL cortical regions. Within the same-state comparisons, greater similarity for room than art attention was observed in all hippocampal subfields, and the entorhinal and parahippocampal cortices. Finally, room-state behavioral performance was strongly and selectively correlated with room-state pattern similarity in the CA2/3 and dentate gyrus subfields of the hippocampus. These results suggest that attention can modulate activity and stabilize activity patterns in the hippocampus and MTL, providing an initial window into how attention affects memory encoding and retrieval.

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36.325 **Phase-amplitude cross-frequency coupling sensitivity to phase shifts and sporadic potentials: possible spurious coupling in ECoG and scalp EEG data** Boaz Sadeh[1](boazsadeh@gmail.com), Andrew Ward[1], Edden Gerber[2], Leon Deouell[2,3], Robert T. Knight[1,4]; [1]Helen Wills Neuroscience Institute, University of California at Berkeley, Berkeley, CA, [2]Department of Psychology, The Hebrew University of Jerusalem, Jerusalem, Israel, [3]Edmond and Lily Safra Center for Brain Sciences, The Hebrew University of Jerusalem, Jerusalem, Israel, [4]Department of Psychology, University of California at Berkeley, Berkeley, CA

Cross-frequency phase-amplitude coupling (CFC) refers to the co-modulation of the power of a fast oscillation and the phase of a slower one, and its use in human and animal electrophysiological studies has grown exponentially in the past decade. Here we show that conventional signal processing tools, and in particular the computation of instantaneous phase of filtered data, may introduce spurious CFC when repeated potentials exist in the data. To demonstrate this, we created two types of simulations. First, we created 1/f pink noise simulating electrophysiological data, and injected Gaussian potentials of various heights and widths with realistic jitters in their temporal separation. We show that upon filtering, the injected potentials cause a systematic shift in the phase of slower oscillations as compared to their original phase in the simulated data, such that the slow wave phase aligns with the timing of the potentials. The average time interval between the simulated potentials dictates the frequency-for-phase of the resulting CFC, whereas the width and height of the potentials mainly modulate the resulting range of the frequency-for-amplitude. Secondly, we used a real EEG dataset that does not feature CFC, and added to it similar potentials as described above. This resulted in strong spurious CFC, even when the added potentials were of low amplitude and were not readily detectable by visual inspection. Next, we show that similar patterns of activity can be found in electrocorticographic data, and suggest several tools that can help disclosing these confounds.

36.326 **Cue validity differentially modulates subunits of the attentional control network** Miranda Scolari[1](mscolari@princeton.edu), Sabine Kastner[1,2]; [1]Princeton Neuroscience Institute, Princeton University, [2]Department of Psychology, Princeton University

There are 18 topographic subunits within fronto-parietal cortex that are known to direct the locus of top-down attention by generating weights in favor of the contralateral visual field. However, it remains unclear how each region individually contributes to the complex process of selection. In a previous neuroimaging experiment, we investigated how the attentional control network signals fluctuations in stimulus position within a visual field. These results supported a functional divergence between subunits: FEF and aIPS are likely involved in integrating information across a hemifield, whereas pIPS is likely involved in fine spatial selection within a hemifield. While the last experiment manipulated stimulus parameters as behavioral goals were fixed, the current experiment is designed to do the opposite. Here we investigate how the control network signals parametric fluctuations in the behavioral relevance of a stimulus by manipulating the validity of a spatial pre-cue. During each stimulus block, gratings appeared at a fixed position on both sides of fixation. A pre-cue indicated whether targets would appear within the left or right stimulus with a pre-specified probability level (50%, 75% or 100% valid), giving five levels of probabilities for each location (0%, 25%, 50%, 75% and 100%). As expected, a contralateral bias was observed across the network when the pre-cue was 100% valid. However, control subunits were differentially modulated by cue validity: while activation within pIPS monotonically increased across all probabilities, aIPS, FEF, and preCC exhibited peaks of activation when the pre-cue was 75% valid. These results suggest that pIPS signals the amount of attention directed to a location, whereas aIPS and FEF are likely involved in attentional disengagement from a high-probable cued location to a low-probable uncued location. This study contributes to the growing body of research which suggests that individuated attentional control subunits are involved in separable aspects of top-down selection.

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36.327 **Predicting moment-to-moment attentional state** Monica D. Rosenberg[1](monica.rosenberg@yale.edu), Emily S. Finn[2], R. Todd Constable[2,3,4,5], Marvin M. Chun[1,2,6]; [1]Department of Psychology, Yale University, [2]Interdepartmental Neuroscience Program, Yale University, [3]Department of Diagnostic Radiology, Yale University School of Medicine, [4]Department of Biomedical Engineering, Yale University, [5]Department of Neurosurgery, Yale University School of Medicine, [6]Department of Neurobiology, Yale University School of Medicine

Although fluctuations in sustained attention are ubiquitous, most psychological experiments treat them as noise, averaging performance over many trials. It would be useful, however, to track and predict trial-to-trial attentional state. The current study does so using multivoxel pattern analysis (MVPA) of fMRI data during n-back tasks of varying load. Stimuli were face images centrally overlaid on scenes; participants were instructed to attend to faces and ignore scenes. Tasks consisted of a baseline 1-back task in which participants responded to every face different than the previous (~90%) and withheld response to repeated faces (~10%); a perceptual load task (1-back with degraded faces); and a working memory load task (2-back). At each correct response, reaction time (RT) variability, calculated as the normalized absolute deviance of that trial's RT from the mean RT of the task, was used an index of attentional state. In each task, participants' 50% most variable trials were labeled "out of the zone" and 50% least variable trials were labeled "in the zone." RT variability has previously been used to track attentional fluctuations (e.g., Esterman et al., 2013), and in the current study predicts performance such that less variable subjects showed higher d'. Linear support vector machine classifiers were trained on voxelwise neural activity to predict each participant's attentional state (in/out of the zone) in each task using a 90-fold cross-validation procedure. Classifiers trained in regions of the default mode and dorsal attention networks, implicated in attentional performance, predicted trial-to-trial attentional state with above-chance accuracy in all three tasks. Classifiers trained in the fusiform face area were successful in the perceptual and working memory load tasks only, while classifiers trained in the parahippocampal place area were only successful in the baseline task. These results suggest that MVPA can be used to predict attentional state on a trial-to-trial basis.

36.328 **Keep your mind on the road: Predicting mind-wandering while driving using classification of pre-probe oscillatory brain activity and driving performance** Jibo He[1](jibo.he@wichita.edu), Cher Wee Ang[2], Adam J. Miller[3], Vinay Maddali[3], John G. Gaspar[2], Ronald S. Carbonari[4], Hank J. Kaczmarski[4], Arthur F. Kramer[2,4], Kyle E. Mathewson[4]; [1]Department of Psychology, Wichita State University, [2]Department of Psychology, University of Illinois, [3]Department of Electrical and Computer Engineering, University of Illinois, [4]Beckman Institute for Advanced Science and Technology, University of Illinois

Mind-wandering, or off-task thought, is believed to be associated with diminished processing of the external sensory environment, while focus is directed at internal dialogue. However, the impact of mind-wandering on driving performance is poorly understood. This study explores the behavioral and EEG oscillatory correlates of mind-wandering while driving in a driving simulator. Drivers followed a lead-vehicle which braked intermittently throughout long drives with random lateral winds. They were asked to report their mind-wandering states both when they caught themselves (self-caught mind-wandering) and when probed by a beep sound (probe-caught mind-wandering) by pressing a button labeled 'yes' on the steering wheel. An additional 'no' button indicated they had been attentive when probed (attentive). Driving dynamics and 32-channel EEG data were compared in the ten second period prior to auditory probes using moving window averaging. Subjects reported mind-wandering about 37% of the time when probed. Results show that mindless drivers drove at higher speed and followed the lead-vehicle at a further distance prior to probes compared to when they were attentive. Evoked ERP activity elicited by probes occurring during mind-wandering showed attenuation of both the N2 and P3 components compared to those presented during attentive periods, revealing diminished processing of external stimuli. The power of delta, alpha, and theta oscillations was also larger during pre-probe mind-wandering than when attentive. Using a multivariate Gaussian mixture model on this time-frequency EEG data over frequency, time, and channels, within-subject classifiers were able to classify untrained pre-probe data as mind-wandering vs. attentive with over 90% sensitivity and specificity, revealing important markers of mind wandering and dangerous driving. This study reveals behavioral and electrophysiological indices that distinguish mindless from mindful driving and provides a foundation for monitoring of drivers whose minds wander behind the wheel.

36.329 **Focal Attention Improves Perceptual Decision-Making by Enhancing Multiplicative Response Gain of Cortical Activity in Human** Sirawaj Itthipuripat[1](itthipuripat.sirawaj@gmail.com), Edward Ester[2], Sean Deering[1], John Serences[1,2]; [1]Neurosciences Graduate Program, UCSD, [2]Psychology Department, UCSD

It is well known that spatial attention facilitates information processing at selected locations. For example, human observers are typically better at discriminating stimuli at attended relative to unattended locations. Several theories for this basic finding have been proposed. One possibility is that selective attention enhances the gain of neural responses in early visual areas (response enhancement). A second possibility is that attention reduces the variability of individual neurons and decorrelates noise within neural populations (noise reduction). A third possibility is that attention improves the efficiency with which sensory responses are "read out" by later decision-making and sensory motor responses (efficient selection). Here, we used a combination of psychophysics, electroencephalography (EEG), and computational modeling to evaluate these alternatives. Participants performed a two-interval-forced-choice contrast discrimination task while attending one or two locations (focused and divided attention conditions, respectively). Contrast-response functions (CRFs) were generated by plotting contrast-dependent changes in the mean amplitudes of early (the P1 ERP component) and late (late positive deflection or LPD) positive-going potentials that peaked over contralateral posterior-occipital (~80-130ms) and central posterior electrodes (~230-330ms), respectively. Consistent with the 'response enhancement' model, we found that focused attention had a multiplicative effect on the P1 and LPD CRFs. Moreover, a computational model that incorporated only changes in multiplicative response gain vastly outperformed models that assume noise reduction or efficient selection. These findings suggest that spatial attention facilitates behavioral performance primarily by enhancing the multiplicative response gain of sensory responses that cascade across processing stages.

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36.330 **Electrical stimulation improves visual attention by speeding the shift of control by long-term memory** Robert Reinhart[1](robert.reinhart@vanderbilt.edu), Geoffrey Woodman[1]; [1]Psychology Department, Vanderbilt University

New evidence indicates that noninvasive brain stimulation can induce safe and reversible improvements in learning during the performance of visual tasks. However, the cognitive mechanisms underlying these learning effects are unknown. Here we show that the improvements in learning are due to changes in how rapidly long-term memory representations replace working memory representations in controlling visual processing. Using transcranial direct-current stimulation of medial-frontal cortex, we selectively enhanced the neural activity related to long-term memory and induced single-trial learning during a memory-guided visual search task. In contrast, medial-frontal stimulation did not change the neural index of working memory in attentional control. Moreover, parietal cortex stimulation spared all measures of top-down control and learning, demonstrating the specificity of the medial-frontal effects on learning during visual processing. In a subsequent experiment, we replicated and generalized our results to a task in which subjects searched for targets among complex real-world objects. Our findings provide new insight into the nature of the memory representations underlying plasticity and learning to control visual attention.

36.331 **Systematic variations in behavioral and electroencephalographic measures of the control of visual attention as a function of body iron status** Stephanie Rhoten[1](serhoten@ou.edu), Michael Wenger[1,2], Elaine Cooper[1], Laura Murray-Kolb[3], Jean-Bosco Gahutu[4], Mercy Lung'aho[5], Jere Haas[2]; [1]Psychology, Cellular and Behavioral Neurobiology, The University of Oklahoma, [2]Division of Nutritional Sciences, Cornell University, [3]Department of Nutritional Sciences, The Pennsylvania State University, [4]The University of Rwanda, Huye , [5]CIAT, Kigali, Rwanda

Iron deficiency (ID) is a highly prevalent micronutrient deficiency in both developed and developing countries, with women of reproductive age being at high risk for developing ID with and without anemia. An accumulating literature suggests that repletion of iron results in substantial improvements in both behavioral and brain measures of visual attention. This improvement in performance is suggested to be due to the role iron plays in two aspects of brain function potentially relevant to visual attention: neuronal energy modulation; and monoamine synthesis and regulation. We report here the results of analyses of baseline data from a randomized, double-blind dietary intervention study involving 257 female

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students (ages 18-26) at the University of Rwanda, Huye; 54 of these participated in the behavioral and EEG testing, using three tasks designed to assess visual attentional capture and control: (a) simple reaction time (SRT), a test of perceptual processing speed; (b) Go/No-Go (GNG), a test of inhibitory control; and (c) the Attentional Network Task (ANT), a test of three critical functions of visual attention: low-level attentional capture, high-level attentional selection, and volitional control under distraction. EEG data were collected using a 64-channel system (BrainProducts, Gilching, Germany), with signals sampled at 250 Hz. We observed statistically reliable relationships between blood measures of iron status and the magnitude (positive) and latency (negative) of two EEG components (P1/N1 and P3); a reliably positive relationship with one measure of overall brain activity (global field power); and a reliably positive relationship with one measure of brain activity specific to engaged attention (power in theta-band activity). In addition, variations in systemic iron levels were systematically related to variations in latencies indicative of attentional capture, selection, and control. We use these initial data to propose a statistical model of the causal effects of body iron status on neural and behavioral functioning.

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Attention: Memory, awareness and eye movements

Sunday, May 18, 2:45 - 6:45 pm
Poster Session, Jacaranda Hall

36.332 The Role of Alerting in Modulating Perceptual Saliency

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In previous work we showed that alerting can induce a global processing bias (Weinbach & Henik, 2011). However, because saliency is often confounded in processing of global features, the present work aimed to investigate the impact of alerting on perceptual processing while controlling for saliency. As in our previous work, participants were presented with a large arrow (global level) comprised of smaller arrows (local level) pointing in the same or opposite directions and had to indicate the direction of the large or small arrows in different blocks. Saliency of the global and local levels was manipulated, creating global-salient and local-salient conditions. Auditory alerting signals were presented in half of the trials prior to the target. Results revealed a double dissociation in the effects of alerting on global/local interference effects as a function of saliency. In a global-salient condition, alerting increased global interference and decreased local interference. In a local-salient condition, alerting reduced global interference and increased local interference. These findings indicate that alerting acts to increase processing of salient visual events, irrespective of the activated perceptual processing mode. In addition, these results challenge previous theories suggesting that alerting acts to increase conflict interference. We showed that alerting can increase or decrease cognitive conflict based on perceptual saliency. We argue that alerting is an adaptive mechanism that diverts attention to salient events, but comes at a cost when selective attention to less salient details is required.

36.333 A size singleton matching the target-distractor size relation cannot capture attention when it appears outside of attentional window

Feng Du[1](duf@psych.ac.cn), Yue Yin[1], Yue Qi[1], Kan Zhang[1]; [1]Key Laboratory of Behavioral Science,Institute of Psychology, Chinese Academy of Sciences

Recent studies have shown that an irrelevant size-singleton cue that matches target-distractor size relation captures attention, resulting in faster RT and a large N2pc to the target at that cued location. By using the spatial blink paradigm, the present study examined whether a peripheral size-singleton distractor that matches the target-distractor size relation can capture visual attention and disrupt central target identification. Three experiments consistently showed that a size singleton that matches a target-distractor size relation cannot capture attention when it appears outside of the attentional window. However, the same size singleton still produces a cuing effect. In addition, a color singleton that matches target color, instead of a size singleton that matches a target-distractor size relation, captures attention when it is outside of the attentional window. In conclusion, a size-relation-matched distractor is much weaker than a color-matched distractor in capturing visual attention and cannot capture attention when the distractor appears outside of the attentional window. Moreover, these results also suggest that a classical Cuing task might not be a sufficient test of contingent capture in the spatial domain. In a classical cuing task, there is no stringent spatial control because the target can appear at any location. In addition, N2pc can be induced by not only involuntary capture but also by voluntary selection of target. Thus a cuing effect along with N2pc is necessary yet insufficient to confirm the presence of contingent capture.

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36.334 Oculometric assessment of visual motion processing

Dorion Liston[1,2](dorion.b.liston@nasa.gov), Leland Stone[1]; [1]NASA Ames Research Center, [2]San Jose State University

Eye movements are the most frequent (~3 per second), shortest-latency (~150-250 ms), and biomechanically simplest (1 joint, no inertial complexities) voluntary motor behavior in primates, providing a model system to assess sensorimotor disturbances arising from trauma, fatigue, aging, or disease states. We developed a 15-minute behavioral tracking protocol consisting of randomized step-ramp radial target motion to assess several aspects of the behavioral response to visual motion, including pursuit initiation, steady-state tracking, direction tuning, and speed tuning. Whereas our initiation and steady-state tracking metrics quantify the motor response, our direction and speed-tuning metrics can be converted into standard psychophysical thresholds. Methods. Observers were asked to pursue a small spot that made an initial step from fixation, then moved back through fixation in a Rashbass (1961) step-ramp design. De-saccaded eye-velocity responses were used to measure: pursuit latency and acceleration during initiation; gain, catch-up saccade amplitude, and proportion of smooth movements during steady-state tracking; direction-tuning anisotropy, asymmetry, and direction noise; and speed-tuning slope and noise. Variations on the step-ramp task were run to evaluate the test-retest repeatability and validity of our task, and to collect a baseline dataset from a population of 41 observers. Results. Our test-retest repeatability evaluation showed that initiation and steady-state tracking metrics were stable enough to allow individual differences to be measured ($p<0.0001$, Kruskal-Wallis). Our validity evaluation showed that initiation metrics show large decrements as the motion stimulus degrades with sampling ($p<0.0001$, ANOVA) and two of three steady-state tracking metrics show more subdued impairments ($p<0.05$, ANOVA). Conclusion. Our method delivers ten metrics that quantify pursuit and saccadic eye movements following a simple 15-minute clinical test, which may be useful as a screening tool for disorders affecting sensorimotor processing.

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36.335 Differential effects of covert and overt orienting on microsaccade rate

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Goal. Previous research has demonstrated that microsaccade rate decreases prior to the onset of a saccade, consistent with lateral inhibitory interactions between fixation and movement neurons at the level of the superior colliculus. We examined whether such suppression is linked specifically to the planning and execution of a saccade of known metrics, or is (i) generalized to conditions where saccade metrics are not completely specified and, (ii) to conditions where observers are planning to covertly shift attention. Methods. We analyzed monocular eye position in thousands of trials across multiple observers in separately blocked covert and overt trials of a discrimination task. Specifically, we examined a fixation interval that was bookended by the onset of a standard stimulus and a directional cue signaling the location of a test stimulus –both covert and overt blocks– and the execution of a saccade –overt blocks only. At the end of the trial, observers performed a discrimination task. Given that the fixation interval was identical for both conditions, any difference in microsaccade rate can be attributed to differences in "task set" between covert and overt blocks. Results. We observed the characteristic biphasic signature of microsaccade suppression (~100-200 ms) and enhancement (~250-350 ms) following the standard stimulus onset for both covert and overt trials. Interestingly, microsaccade rate was suppressed on overt trials relative to covert trials throughout the fixation interval and prior to the saccade. Conclusion. These results reveal that overt and covert "task sets" differentially influenced microsaccade rate, and thus that suppression is not a necessary precursor for preparing to discriminate a target. This finding is consistent with top down influences on microsaccades; it suggests that the "task set" brought about by the preparatory overt and covert states modulates the activity of fixation and movement neurons in the superior colliculus.

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36.336 **An Attention-centered neural marker for shifts in eye position**
Brittany J. Dungan[1](bdungan@uoregon.edu), Edward K. Vogel[1]; [1]Psychology Department, University of Oregon

Past research from our lab has investigated the potential role of visual working memory (VWM) in perceptual stability. We have previously shown that item representations remain in the initial contralateral, encoding hemisphere following a shift in gaze, with items also being represented in the ipsilateral hemisphere over time (Dungan & Vogel, VSS Poster 2012; 2013). Here we extended these findings by recording event related potentials (ERPs) while subjects performed a change detection task for laterally-presented colored squares. Subjects fixated a central cross at the beginning of each trial and were cued to attend to the left or right visual field before the presentation of a memory array. In Experiment 1, on half the trials subjects were cued to maintain central fixation throughout the trial, while on the other half of trials subjects were cued to shift their gaze to a lateral fixation cross presented 8.71 degrees to the left or right. In a blocked design, this eye movement either was over the attended items or away from them. Following the onset of the eye movement, we observed a large contralateral negativity when the eyes were moved over the attended items and a contralateral positivity when they moved away from them. Thus, the polarity of this activity is determined by the relative position of the attended items and was not determined by the absolute direction of the eye movement. In Experiment 2, we manipulated the distance between the central and lateral fixations crosses (7.94 vs. 12.18 deg) and found that the amplitude of the deflection was greater for larger shifts in eye position. Together these results reveal a neural marker of eye position shifts that charts the distance of the shift and is centered to the current focus of attention.

36.337 **Reduced pupillary response in voluntary saccadic task in Parkinson's disease**
Anshul Srivastava[1](anshnbrc@gmail.com), Ratna Sharma[1], Vinay Goyal[2], Sanjay Kumar Sood[3]; [1]Department of Physiology, All India Institute of Medical Sciences, New Delhi, India, [2]Department of Neurology, All India Institute of Medical Sciences, New Delhi, India, [3]Department of Physiology, RAK College of Medicine, UAE

Introduction: Pupil width is widely used nowadays as a measure of attentional allocation in task with cognitive load. When an individual is performing on tasks with varying cognitive load, allocation of attention is reflected by changes in pupil size. Present study aims to find out whether Parkinson's disease (PD) patients have deficit in pupil dilation during voluntary saccadic tasks that has more cognitive demand as compared to reflexive saccades. Methods: Study subjects consisted of age and gender matched, PD group (12 male, Age: 56.17 ± 3.13 year) and control group (12 male, Age: 55.25 ± 3.3 years). In PD group, mean disease duration was 6.42 ± 1.73 years. The study received ethical approval from All India Institute of Medical Sciences (AIIMS) ethic committee. All participants gave informed written consent. Patients were tested on "On medication". Saccadic eye movements were recorded by an infrared-based Arrington Viewpoint eye tracker system. All participants performed on reflexive and voluntary saccade tasks. Both tasks were designed so that horizontal saccades are elicited at 17° to the left or right of the central fixation point. Pupil width at saccade onset was measured. Results: Pupil width during reflexive saccade onset was comparable in PD to control groups. However, during onset of voluntary saccades, pupil size was significantly smaller in patients with PD as compared to control in both gap (p=0.0058) and overlap conditions (p=0.0044). Conclusions: Patients with PD show attentional impairment when made to perform on complex task as compared to simple task (voluntary versus reflexive tasks). We attribute reduced pupillary response in voluntary saccades to deficits in attentional resources in PD patients when compared to controls.

36.338 **The role of conscious perception in contingent attentional capture and working memory updating**
Dominique Lamy[1](domi@post.tau.ac.il), Limor Alon[1], Nir Shalev[1], Tomer Carmel[1]; [1]Psychology, Tel Aviv University

In search for a color, target a precue in the target color captures attention to its location, while a precue in a different color does not, supporting the notion that involuntary capture is contingent on attentional settings. In some cases, irrelevant-color cues even produce the reverse effect, that is, a same-location cost. We recently interpreted this cost as the cost of updating an object representation in working memory when this object changes. Here we use a spatial cueing paradigm in which the target display is clearly visible, whereas the cue display is masked by continuous flash suppression (CFS) and as a result, is invisible on a substantial percentage of the trials. We show that contingent capture occurs also with invisible precues, thereby showing a clear dissociation between attention and conscious vision. In addition, we show that a salient yet invisible stimulus is more likely to thrust into consciousness when it matches the current attentional set (relevant-color cue) than when it does not (irrelevant-color cue). Finally, we show that the same-location cost occurs only when the precue is consciously perceived, thus further validating the hypothesis that this cost is related to working memory.

Acknowledgement: Israel Science Foudation

36.339 **Working Memory Guidance of Attention: Examining the Accessory State Proposal**
Nancy Carlisle[1](nancy.carlisle@gmail.com), Steve Luck[2]; [1]School of Psychology, College of Medicine, Biological Sciences and Psychology, University of Leicester, [2]Center for Mind and Brain, University of California, Davis

Recently, Olivers and colleages (Olivers, Peters, Houtkamp, & Roelfsema, 2011) have suggested that a single item in working memory (WM) influences attention, while other WM items are held in an accessory state. In this study, we examine this prediction by looking at the impact of working memory items over multiple trials searching for the same target. It has been shown that target templates are housed in WM for the first few repetitions of searching for the same target, then moved out of WM (Carlisle, Arita, Pardo & Woodman, 2011). Given the proposal of Olivers, et al. a WM-matching distractor should have little influence on search during the first few trials searching for the same target, as the WM item will be relegated to an accessory state. As the target template moves from WM to LTM across repeated search trials, we would expect to see an increasing attentional impact of WM-matching distractors. In contrast to the proposed increasing WM-distractor effect with increased repetition, we found no significant correlation in WM-distractor effects across 10 trials of repeated search for the same target (r=-.21; p=.55, N=48). This suggests that whether a WM item is relegated to an accessory state is not determined by whether a target template is being held in working memory.

36.340 **Contingent attentional capture by stimuli that match long-term memory representations**
Naseem Al-Aidroos[1](naseem@uoguelph.ca), Maria Giammarco[1], Adriana Paoletti[1], Emma Guild[2]; [1]Psychology Department, University of Guelph, [2]Krembil Neuroscience Centre, University Health Network

Attentional capture serves an important behavioural function—to ensure that salient stimuli in our environment are selected for detailed processing. But what determines salience? This question has primarily been studied by asking what types of low-level stimulus features capture our attention, such as colour or luminance, and how such capture by low-level features is regulated by our top-down goals (i.e., contingent on our attentional control settings). Building off of recent demonstrations that saliency can also be determined by higher-level representations such as conceptual knowledge (Wyble, Folk, & Potter, 2013, JEP:HPP), learned value (Anderson, Laurent, & Yantis, 2011, PNAS), and statistical regularity (Zhao, Al-Aidroos, & Turk-Browne, 2013, Psych Sci), we asked whether stimulus salience can be established based on long-term episodic memory representations. When searching our environment for one of a number of items stored in long-term memory, will stimuli resembling those memories automatically capture attention? To evaluate this question we asked subjects to memorize a set of 30 visual objects and then complete a Posner cueing task, for which the targets were any one of the studied visual objects. Cues were studied or novel objects, either matching or not matching the subjects' attentional goals, respectively. We observed that matching cues produced a cueing effect, but not non-matching cues, suggesting that attentional control settings can be specified based on long-term memory representations, potentially episodic memories. These results add to the growing evidence that salience reflects a complex interaction between internal representations and external features. More broadly, the results also suggest a role for visuospatial attentional capture during the retrieval of long-term memory representations, which may contribute to the rapid recollection observed in recent long-term memory studies (Aly & Yonelinas, 2012, PloS; Guild et al., 2013, PB&R).

Acknowledgement: NSERC

36.341 **The effect of camera presence on arousal, attentional control and inhibition**
William Kendall[1](will.kendall@psych.ubc.ca), Kelsey Chan[1], Alan Kingstone[1]; [1]Department of Psychology, University of British Columbia

Previous research has shown that the presence of a camera can have various profound effects on human behavior, from increasing privacy-related behaviors (Caine, K., Sabanovic, S., & Carter, M., 2012) and pro-social behaviours (van Rompay, T. J., Vonk, D. J., & Fransen, M. L., 2009) to reducing scores on a memory test (Constantinou, M., Ashendorf, L., & McCaffrey, R. J., 2005). In each of these examples, the camera acted as an implied social presence, producing results similar to human observation. More recently, these find-

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ings have been extended to the field of visual attention. Risko and Kingstone (2011) showed that the presence of an eye-tracker leads to changes in looking behaviour. However, looking behaviours are only one measure of attention, and the field contains several other well-established behavioural paradigms. For this reason, we tested participants on a battery of tasks measuring various aspects of visual attention, either in the presence of a camera or not. The battery was comprised of a single- and dual-task version of an attentional capture task, cueing and gaze-cueing tasks, a visual search task, and the Sustained Attention to Response Task (SART). Across these four different visual attention tasks, any effect of camera presence served solely to reduce the response latency of the participants rather than impact the automatic or controlled allocation of visuospatial attention. The single exception to this pattern of results was in the inhibitory control of the automatic capture of attention by a distractor under a condition of high (dual-task) load. These results suggest that the presence of a camera may operate by increasing arousal, thereby reducing reaction time. However, when combined with a cognitive load manipulation, the capacity of attentional inhibition is reduced and so capture by distractors becomes pronounced.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada

Spatial vision: Natural image statistics

Sunday, May 18, 2:45 - 6:45 pm
Poster Session, Jacaranda Hall

36.342 **Measuring the Laws of Natural Vision by Constrained Natural Scene Sampling** Stephen Sebastian[1](sebastian@utexas.edu), Jared Abrams[1], Wilson S. Geisler[1]; [1]Center for Perceptual Systems, University of Texas at Austin

Vision science has identified a number of factors that affect detection threshold for spatial targets in backgrounds. Typically, simple stimuli are used to allow precise experimental control and rigorous hypothesis testing. However, an ultimate goal of vision science is to understand performance under natural conditions, where multiple factors are varying simultaneously in complex ways. We propose a direct experimental approach for identifying and quantifying the factors that affect detection performance in natural scenes. First, we obtain a large representative collection of calibrated natural images. Next, we divide the images up into millions of background patches and sort them into narrow bins along dimensions of interest. For example, in the present study each bin represents a particular (narrow range of) mean luminance, contrast, and spatial correlation of the background to a given target. Next, we measure detection thresholds in humans parametrically for a small subset of bins spanning each dimension. The psychometric function for each bin is measured by randomly sampling (without replacement) background patches from that bin. Finally, we analyze the residual variation of the background patches within each bin for other factors that strongly correlate with the measured performance. In our initial measurements with a 4-cpd Gabor target in two subjects, we find (with background-target correlation fixed) that threshold amplitude is a linear function of mean luminance (Weber's law for luminance) and threshold power is a linear function of background contrast power (Weber's law for contrast). Thus, our results suggest that these classic laws translate to natural backgrounds. However, a preliminary analysis suggests that other factors will emerge beyond the three we controlled for. Finally, we note that this general approach should be applicable to other natural tasks as long as a sufficiently large set of natural stimuli can be obtained.

36.343 **Online Crowdsourcing of Subjective Quality Assessment of Images** Deepti Ghadiyaram[1](deeptigp9@gmail.com), Alan Bovik[2]; [1]Department of Computer Science, The University of Texas at Austin, TX 78712, [2]Department of Electrical and Computer Engineering, The University of Texas at Austin, TX 78712

Significant progress has been made on the problem of designing objective blind image quality assessment (IQA) models that are consistent with human subjective quality evaluations. However, it is vital to be able to validate the performance of every algorithm on extensive, highly diverse ground truth data. Existing image datasets are limited by their size, simulated distortions and their severities, and the human opinion scores are generally collected on a single device having a fixed display resolution and a fixed viewing distance. These limitations motivated us to design and create a new image quality database that models realistic distortions captured using a wide variety of commercial devices and which includes diverse artifacts. We also designed and implemented a new online crowdsourcing system using Amazon's Mechanical Turk, which we have used to conduct a very large-scale IQA subjective study, wherein a wide range of diverse observers record their judgments of image quality. Thus far we have collected over 40,000 human judgments on about 1200 naturally distorted images from over 1000 distinct subjects. The study is ongoing and we plan to collect more than 300,000 subjective judgments overall, making it the world's largest, most comprehensive study of perceptual image quality ever conducted. Furthermore, we have conducted a statistical analysis of the ratings obtained on images from users who viewed them on different devices and from different distances to study the impact of these factors on perceptual quality. We have evaluated several IQA algorithms in regards to their ability to reliably predict the visual quality of the images from our growing database. Thus far we have found that existing blind IQA algorithms have significant room for improvement towards being able to accurately predict the quality of the images suffering from diverse real world distortions that are contained in our database (Table 1).

36.344 **Measuring perceptual differences between compressed and uncompressed video sequences using the swept-parameter Visual Evoked Potential** Anthony Norcia[1](amnorcia@stanford.edu), Justin Ales[2], Emily Cooper[1], Thomas Wiegand[3]; [1]Department of Psychology, Stanford University, [2]Department of Psychology, St. Andrews University, [3] Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute

Video compression algorithms reduce the bit rate needed to transmit video signals. At bit rates relevant to practical transmission scenarios, the compressed video signal differs from the uncompressed one. The compressed signal typically is of lower quality and the degradation relative to the original represents a perceived distortion. Here we introduce an evoked potential method that quickly and objectively measures differences between video signals that are correlated with perceived distortion. A video sequence was subjected to increasing levels of compression through an intra coding method (High-Efficiency Video Coding standard H.265/MPEG-HEVC). To generate an evoked response related to perceptual differences, we alternated between uncompressed and compressed video sequences at 3 Hz. A given level of compression was presented for 1 sec and the degree of compression was increased in equal-sized steps every second, yielding a 16 sec trial. The participants (n=8) pressed a button when they first detected compression modulation. The evoked potential increased monotonically at the 3 Hz compression alternation rate and its harmonics. Thresholds estimated from these functions were well correlated with the behavioral threshold. The scalp topography of the first and second harmonics suggested the presence of at least two mechanisms sensitive to the presented differences. We modeled the generation of the first and second harmonics using a simple image-difference model—by taking the sum of the absolute differences between each pair of frames. This model produced two image-based signals analogous to the evoked potential harmonics. The first-harmonic signal reflected the sustained response to the level of compression, which increased over the trial. A second-harmonic signal reflected the transient differences between compressed and uncompressed frames, which also increased as compression-level increased. Evoked responses thus provide an efficient and accurate measure of two distinct neural correlates of perceptual differences.

36.345 **The perceived blur in natural images is predominantly determined by Off signals** Hiromi Sato[1,2](satoh@l.u-tokyo.ac.jp), Isamu Motoyoshi[3], Takao Sato[1]; [1]Department of Psychology, The University of Tokyo, [2] □□□□ Research Fellow, [3]Department of Life Sciences, The University of Tokyo

Images appear to be blurred as its power at higher spatial frequencies is reduced. The present study examines whether the perceived blur depends on only one or both of the bright/dark (On/Off) contrast polarities. In experiments, the subjective blur of test image in which the power of either On or Off component at higher spatial frequencies is reduced was measured by matching them to reference stimuli in which both On and Off components were reduced by various degree. The test stimulus had 5 levels of blur generated by reducing high-frequency power between 20 and 100%. We found that the image appears to be markedly blurred as compared to the original when Off component is reduced, whereas little effect was observed when On component is reduced. This asymmetry is prominent for a variety of natural images, but also evident for artificial stimuli such as letters and square-wave gratings. We also found that adaptation to a texture composed of small dark dots (Off) made the subsequently presented image more blurred than adaptation to a texture of bright dots (On). These results suggest that Off component within high spatial range is the critical factor determining perceived blur.

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36.346 **Bimodal Distributions of Local Phase Variables in Natural Images**
HaDi MaBouDi[1](maboudi@gmail.com), Hideaki Shimazaki[2], Hamid Soltanian-Zadeh[1,3,4], Shun-ichi Amari[2]; [1]School of Cognitive Sciences, Institute for Research in Fundamental Sciences (IPM), Tehran, Iran, [2]RIKEN Brain Science Institute, Wako-Shi, Saitama, Japan, [3]Control and Intelligent Processing Center of Excellence (CIPCE), School of Electrical and Computer Engineering, University of Tehran, Tehran, Iran, [4]Medical Image Analysis Laboratory, Henry Ford Health System, Detroit, Michigan, USA

Natural scenes contain rich information in their local phase structure compared to their amplitudes. Nevertheless, conventional models of visual systems represent the natural images using superposition of receptive fields (RFs) based on the information contained only in the amplitudes. As a result, the redundancy in the images is not completely removed. Typically, the responses of the RFs after training exhibit circular dependencies. Thus recent studies suggested decomposing images using amplitude and phase coefficients of a complex representation. However, these studies assume uniform phase distributions. Here, we report the presence of structured bimodal distributions for the phase variables of the complex RFs responding to natural scenes, suggesting that the uniform distribution is insufficient to reduce the redundancy of natural scenes. To show this, we first construct a complex RF defined as a pair of Gabor-like RFs possessing the same features such as scales, orientations, and frequencies, but are in quadrature phase. Next, we obtain a phase distribution of its responses to patches selected from whitened natural scenes. The phase distribution was then fitted by a mixture of two von Mises distributions and a uniform circular distribution, using the expectation-maximization algorithm developed for this study. Finally, we apply the complex RFs possessing different features to the natural image patches to investigate variation of the phase distributions with these features. The analysis revealed a half of the complex RFs exhibited bimodal distributions. The distances between two peaks of the distributions were about 180 degree. Importantly, the shape of the distributions significantly varied when the scale or frequency of the complex RFs changed: The complex RFs possessing low frequencies or small scales yielded the bimodal distributions. Our results suggest that the redundancy in the natural images can be further removed if we consider bimodal phase distributions, in particular, for low-frequency / small-scale complex RFs.

36.347 **Bivariate Statistics and Correlations in Natural Images**
Che-Chun Su[1,3](ccsu@utexas.edu), Lawrence Cormack[2,3], Alan Bovik[1,3]; [1]Department of Electrical and Computer Engineering, The University of Texas at Austin, [2]Department of Psychology, The University of Texas at Austin, [3]Center for Perceptual Systems, The University of Texas at Austin

Modeling natural scene statistics and understanding the human vision system have come to be regarded as a dual problem. Great successes have been achieved in the image/video processing and computer vision fields by applying natural scene statistical models to develop perceptually relevant and effective algorithms. However, most natural scene statistical models are characterized only by univariate distributions, while higher-order dependencies between spatially adjacent pixels in natural images are not well-understood or utilized yet. To perform robust bivariate statistical modeling of natural images, we exploited the LIVE Color+3D Database Release-2, which contains 99 pairs of stereoscopic left and right color images with precisely co-registered corresponding ground-truth range maps at a high-definition resolution of 1920x1080. All of the color images were first transformed into the perceptually relevant CIELAB color space. Next, the color images and their corresponding range maps were both subjected to a steerable pyramid wavelet decomposition followed by a divisive normalization using the energies of neighboring coefficients. We examined the statistical relationships between spatially adjacent coefficients over multiple scales and orientations, and modeled the corresponding joint histograms using a bivariate generalized Gaussian distribution (BGGD) augmented by a new correlation model explicitly represented by an exponentiated sine function. To demonstrate the effectiveness of the enhanced BGGD and exponentiated sine correlation models, we applied them to solve a practical problem of depth estimation from monocular natural images. By introducing additional features based on the proposed bivariate statistical models, we boosted the performance of a Bayesian depth estimation framework to achieve better than state-of-the-art performance. We believe that the new bivariate correlation model embeds rich information relating the luminance/chrominance and range information projected from and contained in natural environments. Furthermore, a wide variety of 3D algorithms and applications, e.g., stereoscopic quality assessment, 2D-to-3D video conversion, etc., are to likely benefit from these robust and effective new bivariate statistical models.
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36.348 **Hierarchical correlational structures in natural scenes**
Zhiyong Yang[1,2,3](zhyang@gru.edu), Xiaoyuan Zhu[1], Julian Nussbaum[2,3]; [1]Brain and Behavior Discovery Institute, Georgia Regents University, [2]James and Jean Culver Vision Discovery Institute, Georgia Regents University, [3]Department of Ophthalmology, Georgia Regents University

Natural scenes consist of objects of various physical properties that are arranged in the natural environment in a variety of ways. The higher-order statistics of natural scenes are crucial for our understanding of scene perception, space navigation, space memory, and the underlying neural mechanisms. We propose natural scene structures (NSS), i.e., topology-conserving, multi-size, multi-scale concatenations of features, as the basic features of natural scenes that are at a higher level of abstraction than pixels, edges, junctions, and textures. We took five steps to compile NSS: 1) sample a large number of circular patches in hexagonal configurations at multiple spatial scales; 2) perform independent component analysis on the circular patches and obtain independent components (ICs) at each spatial scale; 3) fit Gabor functions to the ICs and classify the ICs at multiple spatial scales into a set of clusters (referred to as IC clusters) using the parameters of the fitted Gabor functions as features; 4) project the circular patches to the IC clusters, compute the features of the circular patches, and pool the features of the patches in the hexagonal configuration at multiple spatial scales; and 5) partition the space of feature vectors into a set of NSS. The NSS obtained in this way provide a classification of natural scene patches of large sizes (1-10 degrees of visual angle) that include all concatenations of visual features and encode local topology, scaling-invariance, and scaling-variance. We examined the correlation among the NSS and found a variety of correlational patterns that are very different from the 1/f correlation at the pixel level in natural scenes. For example, the correlation may increase with spatial separation or have peaks at various spatial separations. We speculated the implications of these correlational structures on scene perception and the underlying neural mechanisms
Acknowledgement: This material is based upon work supported by, or in part by a pilot award from the James and Jean Culver Vision Discovery Institute, Georgia Regents University.

36.349 **Efficient Coding in Active Perception**
Jochen Triesch[1](triesch@fias.uni-frankfurt.de), Thusitha Chandrapala[2], Sébastien Forestier[1], Luca Lonini[1], Constantin Rothkopf[1], Bert Shi[2], Céline Teulière[1], Chong Zhang[2], Yu Zhao[2]; [1]Frankfurt Institute for Advanced Studies, [2]Hong Kong University of Science and Technology

The efficient coding hypothesis is a powerful guiding principle for studying sensory coding and models derived from it have had impressive successes in explaining early visual representations based on the statistical properties of natural images. Importantly, however, the statistics of inputs to the visual system depend on the organism's behavior and the acquired sensory representations are driving this behavior. Here we describe a novel theoretical framework connecting efficient coding and active perception. The central tenet of this framework is that animals and humans have evolved and/or learned to utilize their motor systems to facilitate the efficient encoding of relevant sensory signals. Thus, instead of movements of body and sense organs just affecting the statistics of sensory inputs, we argue that in many cases they in fact optimize these statistics. In particular, we show how different types of eye movements such as vergence and smooth pursuit movements can be viewed as contributing to an efficient coding of sensory information. Importantly, our framework also proposes a learning mechanism for efficient coding in active perception that combines concepts from unsupervised and reinforcement learning in a novel way by reinforcing eye movements that lead to an improved encoding of the visual input. We show how models based on this framework for efficient coding in active perception autonomously develop accurate vergence eye movements while learning a representation of binocular disparity or develop smooth pursuit eye movements while learning a representation of image motion. This occurs in a robust and self-calibrating fashion driven solely by the objective of improving coding efficiency. Overall, we argue that brains not only utilize visual representations to guide behavior, but they also utilize behavior to improve visual representations.

36.350 **'Natural' image statistics and 'Neoplasticism' – what could be the formula to compose a Mondrian?**
Johannes M. Zanker[1](J.Zanker@rhul.ac.uk), Alexandra Kalpadakis-Smith[1], Szonya Durant[1]; [1]Department of Psychology, Royal Holloway, University of London

Whilst it is common for artists asking questions about the very nature of beauty, and universal aspects of aesthetic experiences, such questions are rarely picked up by scientists. However, psychophysics can make this field of enquiry accessible as demonstrated by Fechner (1876) in his rather

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programmatic experimental aesthetics. A key issue to overcome in such attempts in the visual domain is the apparently huge range and irregularity of possible designs in paintings, and the need to use systematic and well-defined stimuli in psychophysics. On the way towards making actual paintings accessible to psychophysical experimentation, we analysed the 'canonical' paintings of one of the most iconic artists of the 20th century - Piet Mondrian. Mondrian coined the name 'Neoplastic Abstraction' for his works between 1921 and 1939, which are characteristically composed of a grid of horizontal and vertical lines with rectangular colour patches embedded in the grid. We determined sizes, numbers, positions, and colours of paintings, lines and patches for all 55 canonical paintings listed in the catalogue of Mondrian's complete works, generating a database of numerical descriptions for each of these designs. From the database we calculated descriptive statistics of image elements, such as aspect ratios, line positions, patch sizes, colour areas, etc., which not only are characteristic of Mondrian's oeuvre as such, but also reflect his change of style over the 18 years. At an analytical level the statistics are further developed into compound measures such as probability density functions for lines, which can then be used to generate 'synthetic' patterns ('Mondroids') from a small set of parameters that look like paintings from a particular phase. Such Mondroids can now be the basis for systematic experiments, involving psychophysical methods as well as eye tracking, or evolutionary algorithms to study aesthetic preference (see Holmes & Zanker, i-Perception 3, 2012).

36.351 **Border salience reveals a curved global geometry of the perceptual space of local image statistics** Syed M. Rizvi[1](syr3001@med.cornell.edu), Mary M. Conte[1], Jonathan D. Victor[1]; [1]Brain and Mind Research Institute-Weill Cornell Medical College

Local features such as lines, edges, and corners are the elements of form vision. Segmenting an image and estimating its surface properties depend on analyzing the spatial statistics of these components. Thus, visual textures constructed from these features constitute an important "perceptual space," in which distances correspond to the degree to which a texture difference supports the inference of a border. Here, we characterize basic aspects of the global geometry of this perceptual space. To reduce the dimensionality of the space to a practical level, we consider binary images and parameterize them by the configurations present in 2x2 neighborhoods, a strategy that focuses on image statistics that are informative in natural images (Tkačik et al., 2010). This leads to a 10-dimensional space of synthetic images, which constitutes a perceptual space, analogous to the familiar 3-dimensional color space. Our previous discrimination-threshold measurements (Victor et al., VSS 2013) showed that perceptual distances near the origin of this space corresponds to a Euclidean metric, and hence, a locally flat geometry. Here, we use suprathreshold border salience judgments to probe the global geometry of this space. Subjects (N=4) were presented with a brief (120 ms) four-quadrant display, each containing a texture sample. Texture samples were chosen to represent points on a line in the space of image statistics. Subjects judged which of the four texture borders was most salient. The relative salience judgments were then subjected to multidimensional scaling. In some directions, the inferred perceptual geometry matched the linear sampling of the space. But in other directions, the linear sampling of the space translated to a perceptual geometry in which opposite edges of the space were warped inward to meet each other. These findings constrain models for how the perceptual space is constructed, and, in particular, imply that opponent mechanisms alone do not suffice.

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36.352 **Sensitivity to local image statistics is (almost) scale-invariant** Mary M. Conte[1](mmconte@med.cornell.edu), Syed M. Rizvi[1], Daniel J. Thengone[1], Jonathan D. Victor[1]; [1]Brain and Mind Research Institute-Weill Cornell Medical College

Segmenting visual images into objects and identifying their surface properties require the analysis of local correlations, as these define the lines, edges, and texture. The relevant local correlations are captured by image statistics involving two or more nearby points. In natural images, these correlations occur together in a complex fashion, and across many spatial scales. This study asks how visual analysis of these correlations and their interactions depends on spatial scale. To analyze how the visual system processes multipoint correlations individually and in combination, we developed a space of artificial images in which these correlations can vary independently. The space focuses on specific types of correlations that are informative in natural images (Tkacik et al., PNAS 2010); this yields a 10-parameter domain of binary visual textures. Recently we showed that at a single spatial scale (14 min check size), visual sensitivity was concisely described by a Euclidean metric. Here, we extend the analysis to cover a 10-fold range of check sizes. In N=6 subjects, we measured texture segmentation thresholds (4-AFC paradigm) along all coordinate axes of the texture space and in coordinate planes covering combinations of image statistics from first- to fourth-order. Stimulus size (15 deg to 1.5 deg) varied in proportion to check size, to keep the number of checks constant. Over a fivefold range of check sizes (14 min to 2.8 min), sensitivities to all correlations remained in proportion to each other. For 1.4 min checks, sensitivity to two-point and higher-order correlations was selectively diminished, while sensitivity to first-order (luminance-driven) statistics was, as expected, preserved. We conclude that visual sensitivity to local statistics is approximately scale-invariant. Consequently, the tuning of visual sensitivity to the informativeness of image statistics in natural images (Briguglio et al., VSS 2013) holds across spatial scales as well.

Acknowledgement: NIH EY07977

Perceptual Learning: Plasticity and adaptation

Sunday, May 18, 2:45 - 6:45 pm
Poster Session, Banyan Breezeway

36.401 **Lateral Masking Reveals Effects of Invading Activity of Short-Term Visual Plasticity** Dorothy Currey[1](dcurrey@uark.edu), Matthew Gannon[1], Nathan Parks[1]; [1]Department of Psychological Science, University of Arkansas

Short-term visual plasticity refers to alterations of visual representations that occur over periods of seconds to minutes. Short-term plasticity can be readily studied in the human visual system using an artificial scotoma: a stimulus-induced analog of a true retinal scotoma. An artificial scotoma is induced by superimposing a small peripheral gray disc upon a background of dynamic white noise. After several seconds of viewing, the gray disc begins fading from awareness, becoming perceptually filled-in by the surrounding white noise background. Animal neurophysiology has demonstrated that spatial representations within the boundaries of an artificial scotoma become driven by cortical spatial representations beyond the scotoma boundaries (invading activity). Here, we used an artificial scotoma paradigm and lateral masking to provide a psychophysical measure of invading activity in the human visual system. Psychophysical observers were conditioned with an artificial scotoma display for a period of 5.0 seconds (2.0 degree scotoma disc, 5.0 degree eccentricity). Following this conditioning period, a Gabor patch oriented ± 20 degrees was briefly flashed for 48 ms within the boundaries of the artificial scotoma. Two lateral masks (2-degree sinusoidal checkerboards) were also flashed for 48 ms, positioned directly adjacent to the outer boundaries of the artificial scotoma, flanking the Gabor patch location. Lateral masks onset at nine separate SOAs relative to the Gabor (-128, -64, -32, -16, 0, 16, 32, 64, or 128 ms). Lateral masking effects following artificial scotoma conditioning were compared to a stimulus-matched baseline condition. We predicted that the scotoma-induced invading activity should lead to enhanced effects of lateral masking. Comparison of accuracy in the scotoma versus baseline condition revealed exacerbated effects of forward and backward masking at intermediate SOAs. These results provide a psychophysical measure of invading activity in short-term visual plasticity and are consistent with visual feedback playing a role in driving these effects.

36.402 **Does size matter? The effect of different magnitudes of prismatic adaptation on perceptual and motor biases.** Christopher Striemer[1,2,3](striemerc@macewan.ca), Priya Nath[1], Karyn Russell[1]; [1]Department of Psychology, MacEwan University, Edmonton, Alberta, Canada, [2]Centre for Neuroscience, University of Alberta, Edmonton, Alberta, Canada, [3]Glenrose Rehabilitation Hospital, Edmonton, Alberta, Canada

Previous research has demonstrated that rightward shifting prismatic lenses can reduce symptoms of left spatial neglect in patients with right brain damage. This reduction in left neglect symptoms is thought to be related to the fact that rightward shifting prisms require the patient to adjust their movements leftward (i.e., towards the neglected field) to compensate for the rightward visual shift. Similarly, previous studies in healthy individuals have shown that adaptation to leftward shifting prisms, which induce a rightward adjustment in movements, can create "neglect-like" patterns of behaviour (i.e., a subtle rightward attentional bias) on tests of spatial attention and spatial biases. Critically, previous studies of prism adaptation in patients with neglect, and healthy individuals, have only examined the effects of a single magnitude of visual shift (typically 10°) on test performance. This leaves open the question as to whether or not larger magnitudes of visual shift will induce larger effects on tests of attention and

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spatial biases. To examine this question in healthy individuals (n=30) we compared the effects of 8.5° and 17° leftward shifting prisms on a manual line bisection task (i.e., bisecting a line in half using a pen), and a perceptual equivalent of the line bisection task (i.e., judging whether a bisection marker on a line is closer to the left or right end of the line). The results indicated that, for the manual line bisection task, there was a larger rightward shift in bisection performance following adaptation to 17° compared to 8.5° leftward shifting prisms. However, for the perceptual version of the bisection task, participants demonstrated an equivalent rightward shift in perceived midpoint regardless of the magnitude of leftward prism shift. These data are consistent with recent studies indicating that prism adaptation may have differential effects on motor compared to perceptual components of neglect.

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36.403 **Visual adaptation as inhibitory reweighing** Zachary Westrick[1](zackzackzackw@gmail.com), David Heeger[1,2], Michael Landy[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Background: It has been hypothesized that adaptation plays a role in efficient sensory coding. Consider the responses of a population of orientation-tuned neurons to the following stimulus ensembles: 1) all orientations occur equally often; 2) one orientation Θ is biased to occur with greater frequency. Absent adaptation, overrepresenting Θ would cause neurons tuned near Θ to respond more on average, and would produce greater response covariance among these neurons, reducing coding efficiency. In agreement with the efficient coding hypothesis, adaptation to a biased ensemble restores the response amplitudes and covariances evoked by an unbiased ensemble (Benucci et al., Nat. Neurosci., 2013). We propose a computational model of adaptation to explain these findings. Methods: The model consisted of a population of neurons with linear, orientation-selective receptive fields, divisive normalization, and anti-Hebbian learning of normalization weights. For each stimulus presentation, the divisive normalization pools are updated as follows: 1) Measure the products of neural responses for each pair of orientation-tuned neurons. 2) Increase the contribution of neuron i to the divisive normalization pool of neuron j in proportion to this product for pair ij, minus its long-term expected value (fixed for each neuron pair, determined by their relative tuning). We simulated the steady-state behavior and dynamics of this model in response to a biased ensemble of rapidly flashed gratings. Results: Adapting to the biased stimulus ensemble changed the normalization weights, such that the responses amplitudes and covariances were restored to values consistent with the unbiased stimulus ensemble. In agreement with neurophysiological and psychophysical measurements, the resulting tuning curves were suppressed near the overrepresented orientation Θ, and were shifted away from Θ towards flanking orientations. Conclusion: A model of adaptation, in which sensory neurons with greater covariance than is expected update to inhibit each other more, explains the efficient coding of biased stimulus ensembles.

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36.404 **Residual inefficiencies of recovered vision in cortically blind fields – insights from equivalent noise analysis** Matthew Cavanaugh[1,2], Michael Melnick[3], Ruyuan Zhang[3], Mariel Roberts[4], Anasuya Das[1,2], Duje Tadin[1,3], Marisa Carrasco[4], Krystel Huxlin[1,3]; [1]Flaum Eye Institute, University of Rochester, [2]Neuroscience Graduate Program, University of Rochester, [3]Department of Brain and Cognitive Sciences, University of Rochester, [4]Department of Psychology, New York University

Visual perceptual training was recently shown to recover coarse motion direction discrimination abilities in subjects with cortical blindness (CB) induced by damage to the primary visual cortex (Huxlin et al., 2009). Here we investigated: (a) whether such training also improves fine direction discriminations; (b) how training alters processing in CB by measuring how fine direction discriminations are affected by external noise. Seven CB observers and two age-matched visually-intact controls underwent baseline evaluation with controlled fixation. CB observers performed 300 trials/day on a left-right global direction discrimination task (Huxlin et al., 2009). After ~6 months of coarse motion discrimination training, we assessed: (a) fine motion direction discriminations using a same-different task; (b) direction difference thresholds for random dot stimuli containing different amounts of directional noise and analyzed the resulting threshold-vs-noise (TvN) functions. For the CB observers, training improved direction range thresholds for coarse direction discrimination back to normal levels of performance. While subjects also regained some ability to perform finer direction discriminations, difference thresholds at the retrained locations were approximately 3x worse than at corresponding locations in the intact hemifields. Threshold versus Noise (TvN) functions showed that thresholds decreased at all noise levels but primarily at low levels. However, compared to TvN curves in the intact visual hemifield and those of the control observers, the retrained, blind hemifield locations still possessed higher thresholds at all noise levels. Application of the Perceptual Template Model (Dosher & Lu, 1999) and the Linear Amplifier Model (Pelli, 1981) to the global motion discrimination paradigm suggests that training primarily increased signal enhancement (reduced internal noise), and that the residual inefficiency in motion processing may reflect some combination of abnormally high internal noise and inability to exclude external noise that are not completely overcome by training in cortically blind hemifields.

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36.405 **Going beyond blindsight: properties of recovered vision in cortically blind fields** Anasuya Das[1,3](anasuya.das@nyu.edu), Duje Tadin[2], Krystel Huxlin[1,2]; [1]Flaum Eye Institute, University of Rochester, [2]Brain & Cognitive Sciences, University of Rochester, [3]Psychology & Centre for Neural Science, New York University

Damage to the primary visual cortex (V1) or its immediate afferents results in a dense scotoma, termed cortical blindness (CB). CB subjects have some residual visual ability, termed blindsight, which allows them to process and even re-learn to discriminate stimuli with high temporal and low spatial frequency content. The present study asked whether training-induced visual re-learning following V1 damage can be elicited by stimuli outside the spatio-temporal bandwidth of blindsight. Specifically, can coarse orientation discrimination of static, non-flickering gabors be re-learned de novo in CB fields - i.e. without prior or concurrent training with moving or flickering stimuli. Second, can visual re-learning induced by such training transfer to untrained orientation and direction discriminations? Finally, does double training with a motion direction and a static orientation discrimination task provide any advantages in generalization of learning relative to training orientation alone. We found CB subjects are able to relearn static orientation discrimination following single as well as double training. However, a key dissociation emerged in the extent of transfer observed with the double-trained group demonstrating recovery of complex motion discrimination thresholds, including range and motion coherence thresholds, at the orientation-trained locations. The single-trained (static orientation only) group, on the other hand, could only discriminate simple motion stimuli. Both groups of subjects had roughly equivalent, though incomplete recovery of fine orientation and direction discrimination, as well as contrast sensitivity. In conclusion, CB subjects are able to relearn static orientation discrimination in their blind field, but those who train only on orientation discrimination generalize less to untrained motion stimuli. These findings suggest that although complex visual motion may be superior as a training stimulus, the cortically blind visual system is able to relearn to process a much wider range of stimuli than predicted by blindsight alone.

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36.406 **Repeated days of 2 hr visual adaptation create effects that are faster but weaker.** Juraj Mesik[1](mesik002@umn.edu), Stephen A. Engel[1]; [1]Department of Psychology, University of Minnesota

The human visual system continuously adjusts its responses to optimize neural processing in a changing environment, a process known as visual adaptation. Although adaptation has been widely studied, it remains relatively unknown whether its dynamics change as familiarity with the adapting conditions increases. To test this question we introduced subjects into a novel visual environment, and measured adaptation on three consecutive days. Subjects viewed their surroundings through a head-mounted display (HMD), which presented them with filtered video from a camera attached to the HMD. The video was filtered to remove 99% of vertical energy, creating adapting conditions with previously unencountered visual statistics. Adaptation to such vertically deprived input has previously been shown to cause a tilt aftereffect (TAE) consistent with increased sensitivity of vertically-tuned neurons. During each day of the experiment, 7 subjects experienced two hours of vertical deprivation while watching popular films on an external monitor. TAE magnitude was assessed before deprivation, and after 30 minutes and 2 hours of adaptation. During these tests, subjects viewed brief presentations of a plaid stimulus, and used a keyboard to adjust the tilt of the two ~45 deg component gratings until the plaid appeared to contain square checks. Over the 3 days, the TAE grew larger at the 30 min timepoint, by 0.4 deg, but decreased at the 2 hour timepoint by 0.5 deg (statis-

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tical interaction between the two, p <0.04; overall average TAE was about 1.4 deg). Hence, as subjects became more familiar with the filtered visual statistics, the peak level of aftereffect caused by adaptation decreased, while the rate of growth of adaptation toward the peak increased. These results suggest that prior experience may allow the visual system to adapt faster to familiar environments and to limit aftereffects of this adaptation.

36.407 Visuomotor adaptation to random rotation transformations in a continuous tracking paradigm

Katherine Snyder[1](ksnyder@mail.utexas.edu), Lawrence Cormack[1], Mary Hayhoe[1]; [1]Center for Perceptual Systems, The University of Texas at Austin

Stability of visuomotor mapping influences the rate of visuomotor adaptation, with lower stability yielding faster learning and forgetting (e.g. Braun et al, 2009) and the flexibility gained from such quick learning and forgetting can make participants more adversely affected by unexpected perturbations (Seidler et al, 2004). In our studies, participants continuously tracked a randomly moving target on screen with a computer mouse while cursor position was transformed through multiple rotation angles, yielding a rich data set of target and response time series. In study 1, participants experienced blocks where cursor rotation varied sinusoidally with time at a frequency of 0.125, 0.25, 0.5 or 1 Hz. In other blocks the transformation varied in a square wave, or as a weighted sum of sine and square wave. The square wave function resulted in higher distance error after the perturbation from minimum to maximum angle than did the sine wave at the same phase, indicating that increases in perturbation size increase error. Additionally, after the perturbation, peak distance from cursor to target decreased with increasing transformation function frequency. In contrast, distance error increased with increasing transformation function frequency for the 300 ms before the perturbation. Thus, fixed transformations decrease post-adaptation error but increase susceptibility to perturbations. In study 2, rotation angle was disassociated from its rate of change by using a random walk instead of a periodic function. Participants tracked a target through a randomly rotating transformation within three different ranges of angles. Preliminary spike-triggered average analysis suggests that both angle and its derivative contribute to distance error. Additionally, we observed minimum cursor heading errors near the mean angle of each block, indicating participants adapt to the mean angle. Together, these results (and this technique more generally) provide insight about the dynamics of visuomotor adaptation in a naturalistic dynamic tracking task.

36.408 Adapting the oculomotor reference frame

Terence L. Tyson[1](terence@ski.org), Laura Walker[1,2], Anna Ma-Wyatt[3], Donald Fletcher[1,2,4]; [1]The Smith-Kettlewell Eye Research Institute, [2]Envision, Inc, [3]University of Adelaide, Australia, [4]Frank Stein and Paul S. May Center for Low Vision Rehab, CPMC

BACKGROUND Age-related macular degeneration (AMD) impairs central vision and can also impact reaching movements (Timberlake et al., 2011). When the fovea degenerates, a preferred retinal locus (PRL) in the periphery is utilized as the oculomotor reference. Delays in reach initiation may be linked to delays in saccade initiation (Renninger, Ma-Wyatt & Fletcher, 2012), however the cause remains unclear. PURPOSE Determine whether saccade delays are caused by an online re-referencing to the PRL or to delays in target localization. METHODS Maculopathy and control subjects look at and reach rapidly to an isolated visual target. The target is presented in one of 8 directions at eccentricities of 2-12 degrees. Binocular eye movements are measured with an adapted Eyelink 1000, tower mount configuration (head restrained). Reach start and endpoints are timed and measured with a mouse button release and stimulus display contact (ELO touchscreen), respectively. Accuracy and timing feedback is given. Time penalty was adjusted to enforce rapid movements. Monocular microperimetry was performed on maculopathy subjects for central scotoma mapping and PRL localization. Fovea location was obtained by an OCT scan (Optos OCT/SLO). Fixation stability was measured by the OCT/SLO and Eyelink. RESULTS Maculopathy subjects exhibit both a decrease in fixation stability and an increase in misdirected saccades as compared to control observers. Despite the misdirection, PRLs were near the target at time of finger contact. Spatial divergence of saccade endpoints and finger endpoints occur along the fovea-PRL axis, suggesting a role of both reference frames in movement generation. Vector analysis also implies that movements could be PRL-directed, fovea-directed or a directional average of the two. CONCLUSION Eye position signals continue to play a role in eye-hand movement targeting, even in the absence of foveal vision.

Acknowledgement: NIH R01 EY022156

36.409 Sleep Enhancement of Texture Discrimination Performance is Dependent on Training Paradigm

Drew Walker [1](dehoffma@ucsd.edu), Steven Pan[1], Shaheen Modir[1], Timothy Rickard[1]; [1]University of California, San Diego

Previous studies indicate that performance on visual discrimination tasks is enhanced after a delay involving sleep, a result that has been interpreted as reflecting sleep consolidation (Karni, et al., 1994). In the motor domain, however, sleep gains are eliminated when fatigue-reducing spaced practice is used (Rickard, et al., 2008). We applied analogous methodology to test sleep enhancement in a classic texture discrimination task in which subjects indicate whether three slanted lines embedded in an array of lines have a vertical or horizontal orientation. Improvement in this task is measured by a decreased stimulus-to-mask onset asynchrony (SOA), here estimated using a staircase algorithm. Subjects trained on a TDT in the evening and were retested after a 24-hour delay involving normal sleep. Fifteen subjects trained using a standard massed training paradigm involving 192 trials with no breaks. Another 15 trained using an optimized training paradigm. In that condition there were 20s break after every 12 trials to reduce fatigue, and the 192 training trials were randomly interspersed with dummy trials which have been shown to mitigate adaptation effects thought to impair learning (Harris, Gliksberg & Sagi, 2012). Performance in the standard training paradigm was indeed improved on retest. The average SOA (109.6 ms) from the first 8 blocks of Session 2 was significantly decreased compared to the average SOA (137.7 ms) from the last 8 blocks of Session 1, $t(1) = 3.45$, $p = .0014$. However, in the optimized training group we found no evidence of enhancement after sleep, $t(14) = 0.18$, $p= .52$. The group by session interaction was highly significant, $F(1, 28) = 8.4$, $p= .007$. Retinotopic specificity was observed for both groups, indicating that training was sufficient to induce neural changes. These findings invite a theoretical reinterpretation of prior results demonstrating enhanced visual discrimination performance following sleep.

36.410 Action Video Games as a Treatment of Amblyopia in Children: A Pilot Study of a novel, child-friendly action game

Christina Gambacorta[1,2](Christina.Gambacorta@Berkeley.edu), Samuel Huang [3], Indu Vedamurthy[3], Mor Nahum[2,4], Jessica Bayliss[5], Daphne Bavelier[3,6], Dennis Levi[2,1]; [1]Vision Science Graduate Group, University of California, Berkeley, [2]School of Optometry, University of California, Berkeley, [3]Department of Brain & Cognitive Sciences, University of Rochester, [4]Posit Science Corporation, San Francisco, USA , [5]School of Interactive Games and Media , Rochester Institute of Technology, [6]Department of Psychology, University of Geneva, Geneva, Switzerland

Amblyopia is characterized by reduced visual and stereo acuity. Patching or penalization of the nonamblyopic eye is the "gold standard" treatment option for children with amblyopia; however, patching requires ≈ 120 hours per line of acuity (i.e. 0.1 LogMAR), and children do not always comply with this demanding form of treatment. Recent studies (e.g. Li et al., 2011) have shown that playing action video games can lead to improvements in visual and stereo acuity in adults with amblyopia. However, due to the violent nature of these games, they are not suitable for children. Here, we tested the feasibility of a novel, child-friendly game developed using the Unreal Development Kit, specifically designed to provide the therapeutic benefits of action games to children. Training elements of the adult version of the game (Bayliss et al., 2013), including a dichoptic display and gabor patches presented only to the amblyopic eye were maintained, while graphics and sounds were redesigned to be more child-friendly. Seven children, aged 7-13 years old, played the game for 10 hours over the course of several weeks. Visual and stereo acuities were assessed before and after game play. Following training, subjects improved, on average, by 0.11 logMAR, (range 0-0.30 logMAR). This significant change (p<.04) after 10 hours corresponds to a 28% improvement in visual acuity for the amblyopic eye, similar to that achieved by 120 hours of patching. Three of the seven children also improved on a randot stereo test (mean 43", range 20-90"), corresponding to a 48% gain. We conclude that our child-friendly version of an action game shows promise in improving vision in the amblyopic eye. As many children in this age group already play video games, this new therapy could also lead to greater compliance, and therefore larger improvements in visual function than existing treatment options.

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36.411 **Perceptual learning in patients with central scotomata due to hereditary and age-related macular dystrophy** Mark W. Greenlee[1](mark.greenlee@psychologie.uni-regensburg.de), Katharina Rosengarth[1], Carolin Schmalhofer[1], Markus Goldhacker[1], Sabine Brandl-Rühle[2], Tina Plank[1]; [1]Institute for Experimental Psychology, University of Regensburg, [2]Department of Ophthalmology, University Medical Center Regensburg

Hereditary and age-related forms of macular dystrophy (MD) are characterized by loss of cone function in the fovea, leading to central scotomata and eccentric fixation at the so-called preferred retinal locus (PRL). We investigated whether perceptual learning enhances visual abilities at the PRL. We also determined the neural correlates (3-Tesla fMRI) of learning success. Twelve MD patients (eight with age-related macular dystrophy, four with hereditary macular dystrophies) were trained on a texture discrimination task (TDT) over six days. Patients underwent three fMRI sessions (before, during and after training) while performing the TDT (target at PRL or opposite PRL). Reading speed, visual acuity (Vernier task) and contrast sensitivity were also assessed before and after training. With one exception, all patients showed improved performance (i.e. significant decrease in stimulus onset asynchronies and reaction times, significant increase in hit rates) on the TDT. Eight patients also showed moderate increases in reading speed, six patients showed improved thresholds in contrast sensitivity and nine patients showed improved thresholds in a vernier visual acuity task after TDT training. We found an increase in BOLD response in the projections zone of the PRL in the primary visual cortex in nine of twelve patients after training. The change in fMRI signal correlated ($r = .8$; $p = .02$) with the patients' performance enhancements when the target was in the PRL. The results suggest that perceptual learning can enhance eccentric vision and cortical processing in MD patients.

Acknowledgement: Deutsche Forschungsgemeinschaft (Project FOR 1075)

36.412 **Extrastriate Body Area (EBA) Activation is Greatest During Viewing of a Dance Sequence Compared to Visualization and Movement: Evidence for Learning and Expertise Effects** Joseph DeSouza[1,2,3,4](desouza@yorku.ca), Paula Di Noto[1,2,3], Gabriella Levkov[1,4], Rachel Bar[5]; [1]Centre for Vision Research, York University, Toronto, Canada , [2]Department of Psychology, York University, Toronto, Canada , [3]Neuroscience Graduate Diploma Program, York University, Toronto, Canada , [4]Department of Biology, York University, Toronto, Canada , [5]Department of Psychology, Ryerson University, Toronto, Canada

Overlapping regions of the mirror neuron network (MNN) are activated to varying extents during viewing, visualization, and execution of movement (Grèzes and Decety, 2001). Although recent evidence has implicated the extrastriate body area (EBA) as a compensatory visuomotor processing area (van Nuenen et al., 2012, Urgesi et al., 2007), its role in motor execution continues to be debated (Astafiev et al. 2004; Peelen and Downing 2005) and the influences of learning and expertise on EBA activation remain unknown. To clarify the role of EBA in the MNN, we scanned 11 expert ballet dancers and 10 controls using functional magnetic resonance imaging (fMRI) during three tasks: viewing a ballet dance, visualizing a ballet dance, and a motor localizer task. The expert group was scanned up to four times over a 34-week programme to ascertain any putative learning effects within the EBA. Our results show that the viewing task elicited the strongest bilateral EBA activation (left EBA: $F(2,30) = 76.31$, $P<0.001$, right EBA: $F(2,34)= 51.171$, $P<0.001$), with evidence for learning effects and increased bilateral activation during the visualization task over time ($P<0.05$). Finally, significant contralateral EBA activation during movement execution in control subjects only demonstrates its modulation with experience ($P_{Bonf}<0.05$). These results provide a composite of the role played by the EBA as a higher-order visual processing area within the MNN, primarily subserving action observation of complex sequences of naturalistic whole-body movement and modified by experience and motor learning.

Acknowledgement: NSERC

36.413 **Better Batting Through Perceptual Learning** Jenni Deveau[1](jennifer.deveau@email.ucr.edu), Dan Ozer[1], Aaron Seitz[1]; [1]University of California Riverside

Vision is a basic cognitive ability that profoundly impacts an enormous range of personal and professional tasks. Accordingly, numerous studies of perceptual learning examine mechanisms that can improve vision. However a limit of extant studies is that learning effects often fail to transfer beyond the trained task or stimuli and even less so to real world conditions. Here we show results of a new vision training paradigm in which learning principles that have been well established in individual studies are combined to create an integrated training designed to produce broad based improvements to vision. We applied this training program to the University of California Riverside Baseball Team and assessed benefits using standard eye-charts as well as batting statistics from their game season. We found trained players improved their visual acuity and contrast sensitivity compared to untrained players. Analysis of game statistics show that trained players decreased strike-outs, created more runs, and the team won more games than predicted by the previous years performance and typical year-to-year improvements compared to the rest of the league. These results demonstrate real world transferable benefits of a vision-training program based on perceptual learning principles. This training approach has great potential to improve perceptual abilities in individuals, such as athletes looking to optimize their visual skills or as a therapy to help improve vision in individual with low vision.

36.414 **Fear memories in visual cortex: inter-individual differences related to reflex physiology and genetic variants** L. Forest Gruss[1](lo-forest@ufl.edu), Margaret Bradley[1], Andreas Keil[1]; [1]Department of Psychology, University of Florida

Classical fear conditioning is a widely used laboratory model of how humans acquire a fear response. In the present study, we used electroencephalography (EEG), heart rate, skin conductance, the startle response, as well as self-report measures to study inter-individual differences in differential fear conditioning. Additionally, we collected saliva samples to relate genetic polymorphisms (8 selected SNPs implicated in brain plasticity) to cortical and physiological indices of fear learning. We adopted a paradigm with visual grating stimuli that have differential capability to engage luminance versus chromatic pathways of the human visual system. Grating orientation served as the discriminant feature in this conditioning paradigm. A loud (96dB) noise served as the unconditioned stimulus (US). Gratings were presented in a flickering fashion (14Hz) to evoke steady state visually evoked potentials (ssVEPs). We predicted that heart rate (HR) accelerators versus decelerators (Hodes et al, 1985) would show an electrocortical increase to the aversively conditioned stimulus (CS+) during the acquisition phase, solely for the stimulus engaging the luminance pathway. Results revealed three distinct groups of HR responders: accelerators, decelerators and moderate decelerators. As expected, preliminary results show that HR accelerators have significant ssVEP amplitude increase to the CS+ during acquisition. The HR decelerators on the other hand showed the reverse pattern, with a marked decrease of the ssVEP signal to the CS+. These data suggest that although both groups learn the association of the CS+ to the US as per their self-report, the HR accelerators may engage their fear system more strongly, reflected in reflex physiology as well as in visual cortex. Further analyses of how the genetic polymorphisms relate to conditioning effects in the visual cortex, may illuminate the underlying inter-individual differences observed in fear learning.

36.415 **Lateralized insular activation/deactivation as a result of active learning** Lora Likova[1](lora@ski.org), Spero Nicholas[1]; [1]Smith-Kettlewell Eye Research Institute

Learning to draw or to play music are prime examples of complex active learning that engages sensorimotor integration, working memory, perception-action associations and emotions. Recent studies have discovered striking unilateral activation in left insular cortex for listening to melodies previously rehearsed on a musical instrument but not for unrehearsed melodies. It is not known, however, if practice in visual art would have an analogous effect. Methods: Using fMRI before and after active training to draw faces and objects, we compared brain activity under i) passive image viewing, ii) active reproduction by drawing from memory, iii) copying while viewing the images, and iv) non-image drawing (scribble) as a motor-control. Results: As predicted, left insula was activated during viewing of actively practiced images. Remarkably, however, massively increased fMRI responses to practiced vs unpracticed images were found in left anterior insula during both types of image drawing - from memory, and copying (but not for scribbling, thus eliminating pure motor-related explanations). Face and object activation largely overlapped, with face activation significantly stronger and shifted anteriorly. Striking post-training deactivation developed in right insula, which has recently been assigned a critical role in switching between central-executive and default-mode networks. Conclusions. Our results provide evidence against the classic view of perception and action as two extremes of mental operations, and instead support an emerging integrated view. Because these insular regions are involved in the regulation of visceral changes related to emotional states, its differential involvement in skilled drawing and music activities suggests a role in embodied cognition. Moreover, such drawing-related behaviors are a useful model of general perception-action mechanisms, bidirectional

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interactions between the visual and motor systems during active learning and how they develop through training. The functional connectivity and relations of insula with the respective networks will be discussed.

Development: Autism

Sunday, May 18, 2:45 - 6:45 pm
Poster Session, Banyan Breezeway

36.416 **Intact Multisensory Integration of Low-Level Visual and Auditory Information in ASD**

Vanessa Bao[1](vanessa.bao@mail.mcgill.ca), Victoria Doobay[1], Laurent Mottron[2], Olivier Collignon[3], Armando Bertone[1,2]; [1]Perceptual Neuroscience Lab (PNLab) for Autism and Development, McGill University, [2]University of Montreal Center of Excellence for Pervasive Developmental Disorders (CETEDUM), [3]Università degli Studi di Trento, Trento, Trentino-Alto Adige, Italy

Research suggests that deficient multisensory integration (MSI) may partially underlie sensory-seeking or sensory-aversion behaviors in Autism Spectrum Disorders (ASD) (Iarocci & McDonald, 2006). Most of the evidence supporting this hypothesis comes from studies that use socio-communicative stimuli (i.e., speech, faces) or complex cognitive tasks. This study's goal was to investigate MSI abilities in ASD using low-level stimuli that are void of social content to disentangle multisensory integration from the confounding role of a possible social deficit. To do so, 20 adolescents / adults with and without ASD completed 2 low-level MSI tasks. For the flash-beep illusion task (Shams et al. 2000), participants responded whether they saw 1 or 2 flashes (F) while simultaneously hearing 0, 1, or 2 beeps (B). They were exposed to four non-illusion trials (i.e., 2F2B, 2F0B, 1F1B, 1F0B) and two illusion trials (i.e., fission/fusion illusions), whereby a discordant number of flashes and beeps were presented. Illusion susceptibility (i.e., accuracy) was measured. For the target detection task, participants were asked to respond as quickly and accurately as possible (using a button press) to either visual (flash), auditory (beep) or audiovisual stimuli (flash and beep presented together) (Williams et al., 2010). RTs were measured for all conditions. For the flash-beep illusion task, the ASD group was equally susceptible to the fission illusion, and significantly more susceptible to the fusion illusion. This indicates no evidence of impaired MSI in ASD, and may even speak to a more automatic and less selective MSI process. For the target detection task, no between-group differences in RT were found across conditions; both groups demonstrated multisensory facilitation on audiovisual trials. Results suggest that MSI for simple, non-social information is an intact ability in ASD. Since the same participants completed both tasks, we are assessing whether MSI abilities are consistent across tasks for each participant.

36.417 **Assessing lateral interactions within the early visual areas of adults with autism.**

Sabrina Censi[1,2](sabrina.censi@bell.net), Mathieu Simard[3], Laurent Mottron[4,5], Dave Saint-Amour[3,6], Armando Bertone[1,2,5]; [1]Perceptual Neuroscience Laboratory for Autism and Development (PNLab), [2]School/Applied Psychology, Dept of Educational and Counselling Psychology, McGill University, [3]Centre de recherche, CHU Sainte-Justine, Montreal, QC, Canada, [4]Department of Psychiatry, Université de Montréal, [5]University of Montreal Center of Excellence for Pervasive Developmental Disorders (CETEDUM), [6]Département de psychologie, Université du Québec à Montréal

Background. It has been suggested that atypical visuo-spatial perception in autism may originate from altered local connectivity mediating the response properties of early visual feature detectors. The goal of this study was to assess lateral interactions between neurons within early visual areas in autism by measuring steady-state visual evoked potentials (ssVEPs) elicited by windmill-dartboard (Ratliff & Zemon, 1982) and lateral masking paradigms (Polat et al, 1997). Method. Nine participants with autism and 9 typically developing participants, matched for full-scale IQ and age (18-30 years), were asked to passively view visual stimuli during windmill-dartboard and lateral masking paradigms while ssVEPs from four electrodes over the occipital cortex (Oz, POz, O1 and O2) were collected. For the windmill-dartboard paradigm, first- and second-harmonic components of the steady-state responses were used to calculate indices reflecting facilitatory (FI) and inhibitory (SI) cortical interactions for all participants. For lateral masking paradigm, ssVEP data was collected while participants viewed Gabor patches presented either in isolation (target), or flanked by collinear Gabors at different contrasts (8, 16, 30%) at target-flanker distances (1.5λ, 3 λ, 6 λ). Results. Group differences were not evidenced for either FI or SI cortical interaction indices obtained during the windmill-dartboard task. For the lateral masking paradigm, an expected difference between collinear and orthogonal Gabors (presented at a contrast of 16%) at target-flanker distances of 1.5 λ was found in the control group, $p = 0.018$. Importantly, this difference was not evidenced for the autism group. Conclusion. Our results suggest that FI and SI cortical interactions within early visual brain areas are similar in autism and control groups. However, group differences on the lateral masking paradigm are consistent with the hypotheses that lateral connectivity within early visual areas is atypical in autism, and could be considered a possible early neural origin for altered perception in autism.

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36.418 **Perceptual Influences on Cognitive Peaks of Ability in Autism**

Victoria M Doobay[1, 2](victoria.doobay@gmail.com), Vanessa Bao[1, 2], Laurent Mottron[3], Armando Bertone[1, 2, 3]; [1]Perceptual Neuroscience Lab for Autism and Development , [2]School/Applied Child Psychology, Department of Educational and Counselling Psychology, McGill University, [3]University of Montreal Center of Excellence for Pervasive Developmental Disorders

Individuals with autism recurrently demonstrate faster and more accurate performance (cognitive peaks) on the Block Design Task (BDT) subtest of the Wechsler Intelligence Scale. Cognitive accounts suggest that peak BDT performance derives from a reduced "top-down" interference of perceptual cohesiveness of the global figure, whereas perceptual accounts suggest that peaks may originate from superior local visual processing (bottom-up) of component blocks. Using a computerized version of the BDT, the current study assessed whether this characteristic peak originates from a bottom-up perceptual origin by manipulating the visual attributes defining the component blocks of the BDT. Secondly, this study assessed whether there is a relationship in performance difference between manual (traditional) and computerized measures of the BDT. Twenty participants with and without autism completed both traditional and computerized versions of the BDT. For the computerized version, participants were asked to match a centrally presented target design with one of 4 surrounding probes as quickly and accurately as possible, presented on a touch-sensitive screen. The visual attributes of the blocks were manipulated: traditional, red/white; luminance-defined, black/white; or texture-defined blocks. The perceptual coherence of blocks, was also manipulated, where low-coherence (LC) designs necessitated increased local analysis relative to high-coherence (HC) designs. Reaction times in the LC condition were significantly lower in the autism group (i.e., cognitive peak) for the black/white luminance condition only. Correlations between the manual and computerized BDT performance were negative, demonstrating that there is no relationship between performances on these two versions of the test. These results indicate that the characteristic, higher-level visuo-spatial performance in autism, as exemplified by cognitive peaks, may have a perceptual (bottom-up) rather than cognitive (top-down) origin. These results can inform clinical decisions regarding perceptual and cognitive strengths in individuals with autism.

Acknowledgement: Centre de Recherche en Neuropsychologie et Cognition

36.419 **The role of development in locally-oriented visual perception: an investigation spatial contrast sensitivity in Autism Spectrum Disorder**

Jacalyn Guy[1,2](jacalyn.guy@gmail.com), Laurent Mottron[3], Armando Bertone[1,3,4]; [1]Perceptual Neuroscience Laboratory for Autism and Development , [2]Integrated Program in Neuroscience, McGill University, [3]The University of Montreal Center of Excellence for Pervasive Developmental Disorders (CETEDUM), [4]School/Applied Child Psychology, Dept of Educational and Counseling Psychology, McGill University

Autism Spectrum Disorder is characterized by a unique, visual perceptual profile that is best defined by an often- superior ability to process non-social, or elementary, visual information when a local processing strategy is advantageous (Mottron et al. 2006, Behrmann 2006). Several studies suggest that locally-biased perception in ASD may originate at early stages of visual processing, reflected by an increased sensitivity to high-spatial frequency information (Keita, Guy et al. (in review), de Jonge et al. 2007, Jemel et al. 2010). The bulk of these studies, however, have been conducted in adults and older adolescents, neglecting the role of development. It is therefore unclear if locally-oriented perception in ASD emerges early in development and moreover, when exactly it manifests from childhood through to adulthood. The aim of the present study was therefore to examine the development of low-level visuo-spatial perception in ASD in school-aged children and adolescents. Spatial resolution was assessed across three different age groups (i.e. 6-9, 10-12 and 13-15 years), using luminance-defined, sinusoidal gratings defined by different spatial frequencies (0.5, 1, 2, 4, 8 & 16 cycles per degree). Detection thresholds were derived using a two-alternative temporal forced choice paradigm. Contrast sensitivity functions were then defined for each age group. Preliminary analyses failed to reveal a significant group difference in sensitivity. Only expected differences in sensitivity for SF condition and age group emerged. Our current findings indicate that group differences in sensitivity might only be apparent in late adolescence and early adulthood. These results warrant further exploration of the role of experience-dependent modification of neural mechanisms mediating the response properties of early visual processing in ASD.

Acknowledgement: Fonds de Recherche du Québec - Santé (FRQS), Autism Research Training Award, Neurodevnet

36.420 **Atypical Basic Psychophysics in ASD** Bat-Sheva Hadad[1](bhadad22@gmail.com); [1]University of Haifa, Haifa, Israel.

Perceptual atypicalities are increasingly invoked as contributory causes of the fundamental characteristics of ASD. We tested typically developed (TD) individuals and those with an ASD, matched on age and IQ, on basic psychophysics involved in the perception of a single dimension of objects, as well as the processes mediating the integration of these elementary features in perceiving object's shape. The first study tested Weber's law, a psychophysical principle by which minimum detectable increment in stimulus magnitude (JNDs) increases proportionally with stimulus magnitude. Participants had to adjust the diameter of a disc varying in size to match the size of a real disc presented in front of them. Individuals with autism exhibited estimations that did not differ in accuracy from those of TD observers. However, while JNDs increased linearly with object size for TD observers, demonstrating the adherence of visual perception to Weber as early as 4 years of age, the results for individuals on the spectrum showed no such scaling of JNDs with object size. This sensitivity to the absolute metrics of visual information in ASD points to a qualitative difference in physics-perception relationship compared to TD individuals of comparable age and cognitive abilities. In a second study, participants were asked to make speeded classification judgments of the width of rectangular objects while ignoring height. In situations in which the elementary dimensions of an object's shape were perceived in an integral manner in TD, with judgment of one dimension substantially influenced by the other, the same dimensions were treated analytically in ASD. The results document differences in the way visual information is encoded by these two groups, even at a very basic level of processing. Preliminary results in other sensory domains suggest that a general mechanism rather than a visual one might underlie these perceptual alternations in ASD.

36.421 **Increased sampling of motion signals in children with autism** Catherine Manning[1](c.manning@ioe.ac.uk), Steven Dakin[2,3], Marc Tibber[2], Tony Charman[4], Elizabeth Pellicano[1]; [1]Centre for Research in Autism and Education (CRAE), Institute of Education, University of London, [2]UCL Institute of Ophthalmology, University College London, [3]NIHR Biomedical Research Centre at Moorfields Eye Hospital, London, [4]Institute of Psychiatry, King's College London

Difficulties in global motion processing have been reported in autism and interpreted as reduced integration of local motion signals. However, these findings are largely based on the motion coherence paradigm, which is not a pure measure of integration. Elevated motion coherence thresholds could also arise from imprecision in estimating the direction of individual elements, as predicted by accounts of increased neural noise in autism (Simmons et al., 2009). Here, we investigated whether poor global motion processing in children with autism is attributable to increased internal noise and/or reduced sampling. Children with autism aged 6 to 13 years (n=35) and age- and ability-matched typically developing children (n=35) performed an equivalent noise direction disrimination task and a motion coherence task with either slow- (1.5 deg/sec) or fast-moving (6 deg/sec) random dot patterns. In the equivalent noise task, two conditions were interleaved to estimate (i) the finest direction discrimination possible in the absence of noise, and (ii) the maximum amount of noise that can be tolerated whilst making a coarse direction discrimination (±45°). These thresholds were used to fit an equivalent noise function and derive estimates of internal noise and sampling. In the motion coherence task, we measured the minimum proportion of coherently moving dots required for a coarse (±90°) direction discrimination. Unexpectedly, children with autism had comparable motion coherence thresholds and similar levels of internal noise as typically developing children. Even more surprisingly, children with autism were able to pool more dots when estimating global direction than their typically developing peers. Our findings challenge the widespread assumption that children with autism have difficulties with global motion integration. Previously reported difficulties in motion coherence tasks might instead be due to children with autism having difficulties segregating signal from noise.

Acknowledgement: Economic and Social Research Council PhD studentship to Catherine Manning

36.422 **Individuals with autism experience stronger visual capture by shape singletons than neurotypicals** Amrita Puri[1](apuri@uca.edu), Kami Koldewyn[2], Kenith Sobel[1]; [1]Department of Psychology and Counseling, University of Central Arkansas, [2]School of Psychology, Bangor University

Individuals with autism spectrum disorder (ASD) have been reported to perform differently than neurotypical individuals on a variety of visual tasks, including visual search (e.g., Joseph, Keehn, Connolly, Wolfe, & Horowitz, 2009). Accounts of perceptual processing in ASD differ, with influential theories arguing either that these effects are attributable to abnormal bottom-up processing or to abnormal top-down executive control and attentional processes. Here we explored the roles of bottom-up and top-down processing during visual search in participants with ASD and neurotypical controls. In traditional conjunction search tasks, targets share one feature with half of the distractors and a different feature with the other half. When the ratio of distractor types varies, reaction times (RTs) are fastest when either distractor group is small and increase until the distractor groups are equal (the distractor ratio effect). This effect is presumed to be driven primarily by bottom-up signals related to the salience of items in the smaller group. Here, we manipulated distractor color and orientation. Search arrays contained 21 items: one red horizontal target and varying numbers of red tilted and green horizontal distractors. To instill a top-down preference for optimizing search efficiency via color grouping, red distractors were the minority in a greater proportion of trials (Sobel, Gerrie, Poole, & Kane, 2007). The expected distractor ratio effect was observed for both individuals with ASD and neurotypicals when red distractor orientation was 90° from the target orientation; as green distractors became scarce, the unique orientation of the target became increasingly salient. This effect was reduced when red distractor orientation was similar to the target orientation. However, on trials with no green distractors, the ASD group showed greater capture by the orientation singleton, suggesting that visual capture can more effectively overrule a previously established top-down strategy for people with ASD than for neurotypicals.

36.423 **The "Mexican hat" of the attentional focus in autism spectrum disorders** Luca Ronconi[1,2](luca.ronconi05@gmail.com), Simone Gori[1,2], Maria Devita[1], Massimo Molteni[2], Andrea Facoetti[1,2]; [1]Developmental and Cognitive Neuroscience Lab, Department of General Psychology, University of Padua, Italy, [2]Developmental Neuropsychology Unit, Scientific Institute "E. Medea", Bosisio Parini, Italy

It is well established that individuals with autism spectrum disorder (ASD) manifest abnormalities in their visual perception. These abnormalities are sometimes reflected in strengths on detail-oriented tasks, but some others implicate difficulties on distractors inhibition, thus producing sensory overload. In the present study we tested whether these contradictory aspects of perceptual capacity in ASD may be due to a different spatial profile of the attentional focus. Recent neurophysiological models demonstrate that visual selection requiring spatial scrutiny for object recognition elicits – in the immediate surround of the attentional focus – a zone of attenuated excitability, evoking a spatial distribution of attentional resources that resembles a "Mexican hat". This aspect of visual attention was investigated in a group of adolescents with ASD as compared to typically developing (TD) peers matched for age and cognitive level. Our results showed that in the ASD group the attenuation surrounding the focus of attention was markedly reduced, suggesting an unbalanced relationship between neural mechanisms of enhancement and suppression at the locus of attention. Moreover, weaker suppression outside the focus of attention was correlated with higher autistic symptomatology. The present findings give a unique insight into the understanding of visual processing in autism and can help to explain the superior performance in detail-oriented tasks as well as the sensory overload often experienced by individuals with ASD.

36.424 **Orientation discrimination profiles identify distinct subgroups within autism spectrum disorder** Fakhri Shafai[1,4](f.shafai@alumni.ubc.ca), Kimberly Armstrong[2], Grace Iarocci[3], Ipek Oruc[4]; [1]Graduate program in Neuroscience, University of British Columbia, [2]Graduate program in Clinical Psychology, Simon Fraser University, [3]Department of Psychology, Simon Fraser University, [4]Department of Ophthalmology and Visual Sciences, University of British Columbia

The latest revision of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) included the decision to collapse previous diagnostic groupings into a single umbrella diagnosis of autism spectrum disorder (ASD). Although the idea of categorizing individuals on the ASD spectrum into well-circumscribed sub-groups is highly attractive, scientific evidence necessary to make such distinctions is currently lacking. Last year at VSS we presented data from a group of adults with ASD that showed two distinct

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clusters based on performance in an orientation discrimination task. One cluster had results consistent with the oblique effect, i.e., superior precision around cardinal axes, compared to oblique angles. The other cluster of ASD participants showed a complete lack of the oblique effect with flat profiles across all orientations. We hypothesize that this clustering may be a reflection of true etiological sub-groups within ASD. To examine potential links between these clusters defined based on visual performance and ASD symptomology we collected the following neuropsychological measures on the same group of adults with ASD (N=19): 1) Wechsler Abbreviated Scale of Intelligence (WASI-II), 2) Autism Quotient (AQ), 3) Multidimensional Social Competence Scale (MSCS), and 4) Autism Diagnostic Observation Schedule (ADOS). A support vector machine pattern classifier was able to correctly predict which cluster an individual belongs to with generalization accuracy of 89.47% (p =0.01) based solely on Full IQ and gender. In addition, these clusters were also independently identified with 76.92% generalization accuracy based only on a single subscale of the MSCS assessing social motivation (p<0.05) based on a subset of our ASD group (N=13) who completed this measure. Our results suggest that visual performance profiles provide valuable information in identifying true etiological subgroups within ASD. In addition, they suggest that these visual protocols can serve as potential tools to improve diagnostic specificity.

Acknowledgement: This work was supported by the Autism Research Training (ART) Program and NSERC Discovery Grant RGPIN 402654-11.

36.425 **Resistance to distraction in visual search in 2-year-old toddlers with and without Autism Spectrum Disorder (ASD)** Hayley Smith[1](hayley.smith001@umb.edu), Sylvia Guillory[1], Erik Blaser[1], Zsuzsa Kaldy[1]; [1]Department of Psychology, UMass Boston

Background: Previously, we found that 2-year-old toddlers with ASD are much better at visual search than age-matched typically developing (TYP) toddlers (Kaldy et al., 2011, Dev Sci), primarily because they had greater attentional focus (shown by pupillometry, Blaser et al., under revision). The current study directly tested the idea of whether toddlers with ASD are less distractible than TYP toddlers during search. Methods: Stimuli consisted of single-feature (color [red/blue] and shape [circle/rectangle]; set sizes: 9, 13) and feature conjunction trials (set sizes: 5, 9, 13, 17) in mixed blocks. Search displays were presented for 4 s, then the target (always a red circle) rotated; acting as feedback and reward (a unique aspect of our paradigm is that it does not require verbal instructions, making it ideal for populations with weak language skills). Crucially, in the second half of the block of trials, a novel, oddball item was presented in place of one of the usual distractors. A Tobii T120 eye-tracker recorded eye movements. In Study1, 14 TYP toddlers participated (mean age: 24 months) and the oddball item was defined as the conjunction of features present in the display that was disjunct from the target [i.e. a blue rectangle]. In Study2, 13 ASD and 16 age-matched TYP toddlers participated (diagnosis was confirmed by ADOS, mean age: 26 months). Here, the oddball's salience was raised by giving it a novel color [i.e. an orange or green rectangle]. Results: We found that even the less salient oddball of Study1 can have a distracting effect. In Study2, while both groups often fixated the salient oddball, performance of toddlers with ASD was significantly less degraded. Discussion: Our findings provide direct evidence – at the earliest age the condition can be reliably diagnosed – for a stronger resistance to distraction in a search task in ASD.

Acknowledgement: This project was supported by the UMass President's Science & Technology Award and a grant from the Simons Foundation under the auspices of the Simons Center for the Social Brain at MIT (Grant# SCSBMIT) awarded to ZK and EB.

36.426 **"Don't Look": Faces with Eyes Open Influence Visual Behavior in Neurotypicals but not in Individuals with High-Functioning Autism** Alma Gharib[1](agharib@caltech.edu), Ralph Adolphs[1], Shinsuke Shimojo[1]; [1]Division of Biology Caltech, Computation and Neural Systems, Caltech, US.

In tasks examining gaze orientation when viewing faces, open eyes are fixated upon longer than other face regions. High-functioning individuals with Autism (ASD) show inattention to faces and impaired orienting to eyes. In this study, we examined whether impaired orienting in ASD is from avoidance of the eye region or a weaker orienting bias towards open eyes. 13 ASD subjects and 13 healthy controls (HC) group-matched for age and gender viewed Facegen faces while eye-gaze was tracked. Half of the images depicted open eyes (EO) and half depicted closed eyes (EC). Images were presented in three blocks with instructions to 1) view freely 2) avoid the eyes or 3) avoid the mouth. Only controls showed differences in visual behavior for open versus closed eyes. In the "Free-view" condition, within-group comparison showed controls increased their gaze to mouth (p<0.05) and decreased gaze to eyes (p<0.05) for EC over EO, whereas for ASD, gaze to the ROIs stayed the same when viewing both stimulus types. In the "No Eyes" condition, a within-group comparison between stimulus types again showed the ASD group's gaze to ROIs did not change for EO versus EC, whereas controls spent more time on non-face screen regions with EO versus EC (p<0.05), perhaps a strategy to counteract the saliency of open eyes. The ASD group spent similar proportions of time on the eyes as controls in all conditions, indicating there is indeed a tendency to orient to the eye region in the ASD group. For controls however, eyes open versus closed elicited significant changes in gaze behavior, while there was little influence of eyes open versus closed on the ASD group's visual behavior in this sample set, suggesting ASD shows a relative indifference to open eyes versus closed rather than an overall avoidance of eye regions.

36.427 **Don't look at the mouth, but then where? – Orthogonal task reveals latent eye avoidance behavior in subjects with diagnosed ASDs : A movie version.** Connie Wang[1](cxw@caltech.edu), Eiko Shimojo[1], Daw-An Wu[2], Shinsuke Shimojo[1]; [1]Division of Biology/CNS, California Institute of Technology, [2]Caltech Brain Imaging Center, Division of Biology, California Institute of Technology

Background: In the Don't Look paradigm, subjects view images while avoiding specific features, e.g. eyes or mouth in faces, e.g. social or non-social stimuli onscreen. Previous studies (Shimojo et al., VSS '12 & '13) found reduced orienting to social stimuli and reduced gaze to faces and eyes in high-functioning autism (HFA) compared to neurotypical (NT) controls. We extend these studies to investigate gaze differences using video stimuli. Methods: HFA (N=5) and NT (N=6) adults viewed videos of happy and disgusted facial expressions while gaze was monitored. Three conditions specified different instructions: Avoid Eyes (AE), Avoid Mouth (AM), and Free View. Each condition included 4 s and 20 s (5 repeats of 4 s) dynamic changes of expression. Groups were compared on 1) fixation frequencies to the head, face, eyes, and mouth, and 2) slopes of fixation frequencies over time. Results: HFA and NT subjects used different strategies to achieve equal success in avoidance conditions. NTs shifted to unavoided facial features, while HFA subjects split into two subgroups: one (HFA1; N = 2) that shifted within the face at a significantly slower rate (p<0.02 in AE, p<0.006 in AM), and one that shifted outside the face (HFA2; N = 3), looking 30% less at the head and face in AE (p<0.01), and 47% less at the face in AM (p<0.02). For the whole sample, face fixations were negatively correlated with Autism Quotient scores (p<0.01). In the HFA2 group, significant decreases in head (p<0.001) and face (p<0.05) fixations occurred over both stimulus durations. Discussion: Different solutions to the Don't Look problem segregate HFA subgroups from NT controls. One HFA subgroup lacks the tendency to focus on and maintain interest in socially relevant facial features, while the other attends more slowly to these features.

Acknowledgement: JST.CREST, Caltech CBIC.

36.428 **Facial identity is encoded relative to the norm in adults with autism spectrum disorder** Jennifer A. Walsh[1](walshj5@mcmaster.ca), Daphne Maurer[1], Mark D. Vida[1], Gillian Rhodes[2], Linda Jeffery[2], M.D. Rutherford[1]; [1]Psychology, Neuroscience & Behaviour, McMaster University, [2]School of Psychology, University of Western Australia

Face identification is thought to involve implicit evaluation of how an individual face differs from a face prototype (norm-based coding) (Rhodes et al., 2005). The characteristics of the prototype are thought to be influenced by experience with faces. People with autism spectrum disorders (ASD) appear to have both deficits and areas of preserved processing in face perception (e.g., Weigelt, Koldewyn, & Kanwisher, 2012). We examined the extent to which adults with ASD show evidence of norm-based coding of facial identity. Participants were adapted to faces that differed from the average in the physically opposite way that the target face did (an anti-identity), and then asked to categorize the average face. The norm-based model would predict that the average face would be perceived as more like the target identity; a phenomenon known as a face identity aftereffect. The adapting faces were either very different from the average face (80% anti-identity strength) or close to the average face (40% anti-identity strength). The norm-based coding model predicts that more extreme adapting faces should produce a larger aftereffect than less extreme adapting faces. Both the ASD and control groups displayed larger identity aftereffects for more extreme adapting faces compared to weaker adapting faces, evidence that both groups use norm-based coding. There was no group difference in aftereffect size. This pattern is in contrast with previous findings of abnormally small identity aftereffects in children with ASD (Pellicano et al., 2007). The current results provide the first evidence of intact norm-based coding of facial identity in high-functioning adults with ASD, and suggest that deficits in face processing observed in this population may arise from another source.

Acknowledgement: Australian Research Council Centre of Excellence in Cognition and its Disorders ARC Professional Fellowship ARC Discovery Outstanding Researcher Award Social Sciences and Humanities Research Council

36.429 **?Perception of hierarchical figures in ADHD: A unique difficulty in seeing the trees** Lilach Shalev[1,2](lilachsm@tauex.tau.ac.il), Carmel Mevorach[3], Ayelet Baisa[1], Nir Shalev[1,4], Anna Vaskevich[4], Dana Mohaban[4]; [1]Education, Tel-Aviv University, [2]Neuroscience, Tel-Aviv University, [3]Psychology, University of Birminham, [4]Psychological Sciences, Tel-Aviv University

In the present study we examined the ability of individuals with Attention Deficit Hyperactivity Disorder (ADHD) to inhibit responses to irrelevant stimulus aspects in conflicting global and local levels of processing. We administered a modified version of the Navon's letters task to adolescents with ADHD and to age- and gender-matched control group. Participants identified the global and local levels of hierarchical figures which were presented in three different display sizes effectively manipulating the visual angle of the local and global elements. Across the size manipulations our control participants showed local precedence and a larger local-to-global interference (with the local elements identified quicker than global ones and harder to ignore when responding to the global shapes). Interestingly, results showed that participants with ADHD had the reverse effect across the size manipulations. For ADHD, global precedence and interference were evident. Although such performance in ADHD is reported here for the first time, it is in fact, in line with one of the clinical symptoms for ADHD (in DSM) which highlights a difficulty in ADHD to attend to details. Thus, it may be the case that in ADHD, either as a consequence of a perceptual characteristic or as a result of altered attention an exaggerated global precedence imposes a challenge in attending to details.

Acknowledgement: Israeli Science Foundation

Development: Amblyopia

Sunday, May 18, 2:45 - 6:45 pm
Poster Session, Banyan Breezeway

36.430 **Overlapping but non-interacting neural populations in early visual cortex of a human subject with no optic chiasm.** Benjamin T. Files[1](bfiles@usc.edu), Farhan Baluch[1], Pinglei Bao[1], Chris Purington[2], Bosco S. Tjan[1,3]; [1]Neuroscience, University of Southern California, Los Angeles, CA, [2]Vision Science Graduate Group, University of California, Berkeley, CA, [3]Psychology, University of Southern California, Los Angeles, CA

Achiasma is a congenital condition in which the optic chiasm does not develop. Consequently, all retinal efferents from each eye project only to the respective ipsilateral cerebral hemisphere. In the early visual cortex (EVC), the representation for the left and right visual hemifield are "folded" onto each other such that each small patch in EVC has two population receptive fields (pRFs) situated symmetrically across the vertical meridian. Our earlier work has shown that within each small patch of EVC, there reside two sub-populations of neurons, each serving one of the two pRFs. The physical proximity of these sub-populations in cortex may suggest that they have local neural connections, but extensive psychophysical testing has failed to detect any inter-field interactions. Here we used EEG to detect neural interaction between the two sub-populations in EVC. Using frequency-tagged stimuli with different frequencies in the two visual hemifields, we found steady-state visual evoked potentials (SSVEP) at intermodulation frequencies, demonstrating the presence of inter-field neural interactions. However, source localization suggested that the neural loci of these intermodulations were not in EVC (V1-V3). Next, we placed stimuli in either the upper or lower visual field in order to test whether the sources of intermodulation followed the expected pattern of dorsal or ventral EVC, as computed using a cortical model based on the subject's own anatomy. Intermodulation sources did not follow the expected pattern, which again suggests that the locus of inter-field intermodulation is outside of EVC. These findings, along with prior work, support the hypothesis that in achiasma, early visual cortex consists of sub-populations separately representing the two visual hemifields that are physically overlapped but do not interact.

Acknowledgement: EY017707 and NSF BCS-1255994.

36.431 **Comparing V1 between myopes and emmetropes**. Konogan BARANTON[1](barantok@essilor.fr), Thien Huong NGUYEN[2], Masaki YOSHIDA[3], Guillaume GIRAUDET[4]; [1]Essilor International R&D optique, Paris, France, [2]Department of Neuro - Imaging, Centre Hospitalier National d'Ophtalmologie des XV - XX, Paris, France, [3]Department of Ophthalmology. Jikei University School of Medicine, Japan, [4]Essilor CANADA

Introduction : Beyond their refractive distinction, Myopes and Emmetropes show behavioral differences, especially in the presence of blur. Our study's aim is to compare cortical responses in the primary visual cortex (V1) between the two populations and explore correlations with optometric measurements. Protocol : We studied 21 young adults (18 to 35 years), including 10 Myopes and 11 Emmetropes. The total wavefront aberration with natural pupil diameter is measured for both eyes without correction. Once equipped with their visual correction, they undergo an fMRI exam at 3T. This includes a sequence of retinotopy and stimulation for 18s, viewing natural images or tables of optotypes, either sharp or with a 2 diopter artificial blur. To maintain the subject's attention, a detection task of gradual reversal of blur level was introduced at the end of the stimulation (last 6 seconds). Analysis : Data were processed with BrainVoyager and Matlab. The parts of V1 corresponding to the fovea, the perifovea and 3° of eccentricity, were located for each subject. Then cortical activity was integrated over the static stimulation duration. Values obtained were compared with optometric measures. Results : The main significant correlations are between the mean total wavefront aberration of both eyes (rms) and perifovea. For Myopes correlations are for sharp scenes (left, right and both hemisphere $R^2 = 0.64$, $p = 0.01$) and sharp optotypes (right and both hemisphere $R^2 = 0.58$, $p = 0.01$). For Emmetropes correlations are significant only for the left hemisphere activity for sharp optotypes ($R^2 = 0.46$, $p = 0.02$) and sharp scenes ($R^2 = 0.38$, $p = 0.04$). Conclusion : The level of cortical activity of V1 corresponding to the perifovea of corrected Myopes remains correlated with the total wavefront aberration, when taking into account both ametropia and pupil diameter. This correlation is much weaker for Emmetropes.

36.432 **Receptive field properties of V1 and V2 neurons in amblyopic macaque monkeys revealed with local spectral reverse correlation** Romesh D. Kumbhani[1](romesh.kumbhani@nyu.edu), Najib J. Majaj[1], Luke E. Hallum[1], Christopher Shooner[1], Corey M. Ziemba[1], J. Anthony Movshon[1], Lynne Kiorpes[1]; [1]Center for Neural Science, New York University

Amblyopia is a visual disorder associated with disruptions of conjugate binocular vision in early life, which cause a loss in visual performance usually in one eye. Previous studies explored the neurophysiological basis of the amblyopic deficit using single-unit recordings, but the results incompletely explain the perceptual deficits. Advances in recording technology now allow us to examine activity simultaneously over larger areas of cortex. We recorded from V1 and V2 using 96-channel, multi-electrode arrays in anesthetized, amblyopic and control monkeys. Arrays were implanted in foveal and parafoveal cortex, recording single units and multiunit clusters representing eccentricities between 0.5° and 5°. We characterized the response properties of the heterogeneous population of recorded neurons with local spectral reverse correlation (LSRC), a form of spike-triggered averaging (Nishimoto et al, J Neurosci 26:3269, 2006). We presented dense, ternary, dynamic white noise alternately to each eye in 5-min blocks. We reverse-correlated spike trains with the local 2D amplitude spectrum of the stimulus. On average, each array yielded 45 sites with significant spectra; we measured receptive field location, size, orientation and spatial frequency tuning, and eye dominance for each site. Neurons in amblyopic animals were dominated by the fellow eye, most strongly in the foveal representations. In anisometropes, sites driven by the fellow eye were tuned to higher spatial frequencies than those driven by the treated eye. In contrast, strabismic amblyopes and controls showed no difference in the distribution of preferred spatial frequencies between the eyes. Our multisite recordings allowed us to map the receptive field locations on the cortical surface in detail. We observed no differences in these maps among the tested animals or eyes. We conclude that the eye dominance and visual response properties of cortical neurons but not their retinotopic organization can be altered by experimental amblyopia.

Acknowledgement: NIH EY05864

See page 3 for Abstract Numbering System

36.433 Abnormal surround suppression in amblyopic macaques
L.E. Hallum[1](hallum@cns.nyu.edu), N.J. Majaj[1], C. Shooner[1], R.D. Kumbhani[1], C.M. Ziemba[1], J.A. Movshon[1], L. Kiorpes[1]; [1]Center for Neural Science, New York University

Amblyopia is a developmental disorder causing form vision deficits in the affected eye. Human psychophysics has shown that the representations of both luminance-defined and contrast-defined "2nd-order" forms are affected. Neurons in V1 and V2 of normal macaques typically show surround suppression (SS): the response to a grating is attenuated when the grating extends beyond the classical receptive field, stimulating the extraclassical surround. Since SS confers 2nd-order sensitivity to neurons, we wondered whether SS in amblyopic macaque V1/V2 would be abnormal. We analyzed data collected from 96-electrode "Utah" arrays implanted near the putative V1/V2 border at two eccentricities (0.5-3.0 deg) in each hemisphere of three anesthetized macaques (one control, two strabismic amblyopes). RFs were stimulated using (1) a grating presented through a circular aperture of varying diameter ("area summation"), and (2) large contrast-modulated (CM) gratings presented to both eyes simultaneously. Grating SF and orientation were selected based on preliminary measurements to vigorously drive overall responses. We quantified SS using an index: SSI = (Rp-Rf)/(Rp-Rb), where Rp, Rf and Rb are peak response, response to a full-diameter aperture, and response to a uniform, mean-luminance field, respectively. We used area summation responses to estimate the SSI in the eye ipsilateral (SSIi) and contralateral (SSIc) to array implantation. We ensured that the comparison between median SSIi and SSIc was not biased by the relative position of stimuli in each eye. In the control, SSIi was greater than SSIc: 0.54 versus 0.41 ($p < 0.05$ Wilcoxon rank sum test). This difference was smaller in the mild strabismic: 0.57 versus 0.52, and reversed in the deep strabismic: 0.26 versus 0.64 ($p < 0.05$). Our data suggest that SS is abnormal in amblyopic V1/V2, and this abnormality may underlie reported deficits in 2nd-order form perception.

36.434 Neural correlates of amblyopia in foveal and parafoveal visual cortex of amblyopic macaque monkeys
Christopher Shooner[1](shooner@nyu.edu), Najib J. Majaj[1], Romesh D. Kumbhani[1], Luke E. Hallum[1], Corey M. Ziemba[1], J. Anthony Movshon[1], Lynne Kiorpes[1]; [1]Center for Neural Science, New York University

Amblyopia is a developmental disorder in which spatial vision is impaired in one eye. The physiological basis for amblyopia is unknown, but previous work has shown that the amblyopic eye often influences fewer cortical neurons than the non-amblyopic eye, and that these neurons prefer lower spatial frequencies on average. Earlier studies relied on single electrode recordings made in the representation of the parafovea in V1. We have now used 96-electrode arrays to record neuronal populations representing foveal and parafoveal visual space in areas V1 and V2 of 5 anesthetized and paralyzed macaques, 4 amblyopes and 1 control. Two amblyopes were anisometropic and two were strabismic. We recorded single neurons and multiunit clusters representing eccentricities between 0.5˚ and 5˚. A binocular mirror system allowed independent visual stimulation of each eye. We presented filtered spatiotemporal noise, each sample of which contained power in one of 6 spatial frequency bands with center frequencies ranging from 0.5 to 16 c/deg. We quantified eye dominance and spatial frequency preference for each recording site. All amblyopes tested showed eye dominance bias greater than that seen in the control animal. This bias was significantly greater in the fovea than in the near periphery in 3 of 4 amblyopes; one deep amblyope showed a strong bias at all eccentricities. In both anisometropic amblyopes, neurons driven by the dominant eye preferred higher spatial frequencies than those driven by the non-dominant eye, independently of eccentricity. This effect was evident in the foveal representation of one strabismic animal and altogether absent in the other animal. These observations confirm that experimental amblyopia affects both eye dominance and spatial frequency preference in early visual cortex. These effects depend both on the type of amblyopia (strabismic vs anisometropic) and on location in the visual field.
Acknowledgement: NIH EY05864

36.435 Perceptual Visual Distortions in Juvenile Amblyopes
Marianne E. F. Piano[1](Marianne.Piano@gcu.ac.uk), Anita J. Simmers[1], Peter J. Bex[2]; [1]Vision Research Group, Department of Life Sciences, Glasgow Caledonian University, [2]Schepens Eye Research Institute & Department of Ophthalmology, Harvard Medical School

Introduction: Adults with amblyopia have been shown to experience monocular and dichoptic distortions of their visual perception. The current study aims to measure for the first time dichoptic distortion in children with amblyopia undergoing routine amblyopia treatment, and relate measured perceptual visual distortions to amblyopia features and clinical outcomes of amblyopia treatment. Methods: Children undergoing standard amblyopia treatment had perceptual visual distortion measured within the central 5° of the visual field. The task was mouse-based target-clicking on a stereoscopic LCD monitor, viewed dichoptically through active shutter glasses. The amblyopic eye viewed the cursor and fellow eye the target dot (presented in 16 locations). Global distortion index (mean vector displacement in degrees of mouse-click location from target dot location) was compared to age-matched control children without amblyopia. Results: Amblyopic subjects (n = 13, mean age 6.19 ± 0.99 years) had a significantly greater global distortion index than age-matched control children (n = 140) (0.76° ± 0.56°, vs. 0.41° ± 0.12°, p = 0.001). Global distortion index appears affected by amblyopia type: strabismic/mixed amblyopia was associated with the highest global distortion index (1.00° ± 0.73°), followed by microtropic amblyopia (0.68° ± 0.27) and anisometropic amblyopia (0.41° ± 0.26°). It was not significantly correlated with interocular acuity difference at treatment commencement, number of lines VA improvement, treatment duration, or current VA/refractive error in either eye. Conclusions: Children who have undergone amblyopia treatment experience distorted perception under dichoptic viewing conditions, independent of the VA improvement gained from standard amblyopia treatment practices. These findings suggest that current amblyopia treatment regimens aimed at improving VA/contrast sensitivity do not address the behavioural consequences of utilising amblyopic vision.
Acknowledgement: Fight for Sight studentship

36.436 Comparing dichoptic action video game play to patching in adults with amblyopia.
Sean Noah[3](seannoah@gmail.com), Jessica Bayliss[1], Indu Vedamurthy[2], Mor Nahum[3], Dennis Levi[3], Daphne Bavelier[2]; [1]School of Interactive Games and Media, Rochester Institute of Technology, Rochester, USA, [2]Department of Brain & Cognitive Sciences, University of Rochester, Rochester, USA, [3]School of Optometry, University of California, Berkeley, Berkeley, USA

Adults with amblyopia, a condition characterized by reduced visual acuity (VA) and stereopsis, may benefit from playing action video games with the non-amblyopic eye patched (e.g. Li et al., 2011). However, it is unclear whether these patients can benefit merely from patching of the non-amblyopic eye (i.e. no game), the gold standard for amblyopia treatment in children. We addressed this question by directly contrasting the effects of playing action video games with those of patching. Thirty-two amblyopic adults were assigned to either play 40 hours of a dichoptic action game we developed ('game group', n=16; see Bayliss et al., 2013), or watch action movies with the non-amblyopic eye patched ('patching group', n=16). Following a two months no-contact period, game group participants crossed over to the patching-plus-movies treatment. VA was assessed at baseline and every 13 hours of game/movies treatment. We found that for the game group, VA improved by 26% on average (26%±3.2; p<.000001), regardless of clinical etiology (anisometropia or strabismus). Surprisingly, anisometropic amblyopes (n=7) in the patching group showed VA improvements comparable to those of the game group (n=7; 32%±4.4; p<.0005), and retained the benefits for at least two months after training. In contrast, strabismic amblyopes in the patching group showed no improvement (.01%±6.8). Game group participants maintained their gains throughout the cross-over period. However, no additional benefits from patching were noted during the cross-over period beyond those gained in the game period, for both anisometropic and strabismic amblyopes. We conclude that a dichoptic action game shows promise as viable treatment for amblyopia, as it improves VA for anisometropic and strabismic adult amblyopes, and the improvements are retained for at least two months following training. Supervised patching, however, is only effective for anisometropic amblyopes.

36.437 Is Action Video Game Training Able to Prevent Future Reading Impairment?
Simone Gori[1,2](simone.gori@unipd.it), Sandro Franceschini[1], Milena Ruffino[2], Maria Enrica Sali[2], Massimo Molteni[2], Andrea Facoetti[1,2]; [1] Developmental and Cognitive Neuroscience Lab, Department of General Psychology, University of Padua, Padua 35131, Italy, [2]Developmental Neuropsychology Unit, Scientific Institute E. Medea, Bosisio Parini, Lecco 23842, Italy

Learning to read is extremely difficult for about 10% of children; they are affected by a neurodevelopmental disorder called dyslexia. The neurocognitive causes of dyslexia are still hotly debated. To date, dyslexia prevention is only a dream far from being achieved. Here, we demonstrate that only 20 hours of playing action video games—not involving any direct phonological or orthographic training—drastically improve early visual and auditory predictors of future reading abilities in pre-reading children at risk of dys-

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lexia. We tested rapid naming, letter recognition, auditory-phonological skills (i.e., earliest predictors of reading acquisition) and visuo-attentional abilities in three matched groups of pre-readers at familiar and cognitive risk of dyslexia before and after they played action, non-action video games or no-treatment for 20 sessions of 60 minutes per day. We found that only playing action video games improved children's visual and phonological predictors of future reading abilities. Temporal and spatial attentional skills improved during action video game training and correlate with both visual and auditory-phonological reading predictors. It has been demonstrated that action video games efficiently improve attention and reading abilities in children with dyslexia; our results showed, for the first time, that these attention improvements can directly translate into better language abilities, providing a new, fast and fun prevention training for dyslexia that has theoretical relevance in unveiling the causal role of attention in reading acquisition.

36.438 **Is the Cortical Magnification reduced for the amblyopic eye?**

Simon Clavagnier[1](simon.clavagnier@mcgill.ca), Serge O Dumoulin[2], Robert F Hess[1]; [1]McGill Vision Research, Department of Ophthalmology, McGill University, Canada, [2]Experimental Psychology, Helmholtz Institute, Utrecht University, Netherlands

Amblyopia is a disorder characterized by the reduced vision through one eye due to a disruption of normal visual development (because of strabismus, anisometropia, or deprivation). Its site is not retinal but is thought to be cortical. A number of previous investigations have suggested that either less cortex is allocated to the amblyopic eye or the cortical magnification factor (CMF) is reduced for the amblyopic eye (a selective foveal loss of cortical representation for central vision). We set out to answer the question of whether the cortical magnification in the striate cortex (V1) differed between the amblyopic and fellow sighted eyes of individual with amblyopia. We used the pRF mapping approach to estimates the parameters of an explicit model of the population of receptive fields within a voxel. With this analysis it is possible to determine the cortical magnification factor (CMF) as a function of retinal eccentricity. To reveal any V1 functional abnormalities, we compared fMRI activations across the central 6° between the fellow fixing (FFE) and amblyopic eyes (AME) of 5 severe amblyopes. Data were collected on a 3T scanner under monocular fixation with eye-movement monitoring using an Eyelink system. For both the fellow sighted and amblyopic eyes, PRF sizes increase and CMF decreases with eccentricity in V1. CMF in Amblyopes did not vary between FFE and AME activation and was similar to control subjects. We conclude that amblyopes, even if severe, do not have reduced cortex allocated to the fovea of their amblyopic eye in V1.

Acknowledgement: Supported by MOP-53346 CIHR grants.

36.439 **Higher-order Vision in Adults born at Extremely Low Birthweights**

Terri Lewis[1](lewistl@mcmaster.ca), Louis Schmidt[1], Daphne Maurer[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University

Children born very prematurely later show deficits in higher-order vision, including global form, global motion, and biological motion with four times larger deficits in perceiving global motion than in perceiving global form (e.g., Atkinson & Braddick, 2007; Taylor et al., 2009). To determine whether any deficits are permanent or merely reflect slower visual development, we tested higher-order vision in 15 adults who had been born at <32 weeks gestation with an extremely low birthweight (M age at test=32.3 yrs, range 30–34 yrs; M birthweight=814 gms, range 600–1,000 gms) and in 14 comparably-aged adults who had been full-term and weighed at least 2500 gms at birth. Participants all had no neurological deficits such as cerebral palsy, decreased IQ, or seizures. All had normal or corrected-to-normal visual acuity. We used staircase procedures to measure sensitivity to (a) global form using concentric Glass patterns, (b) global motion at two speeds, and (c) biological motion. Surprisingly, the two groups performed comparably on all tasks. Specifically, sensitivity to global form was normal (signal threshold=13.6% in those born prematurely and 13.3% in controls, p>0.90). Sensitivity to global motion was normal, both when tested at 18 deg/sec (coherence threshold=25.7% in those born prematurely and 19.5% in controls, p>0.10) or at 4 deg/sec (coherence threshold=37.0% in those born prematurely and 23.7% in controls, p>0.10). Sensitivity to biological motion was also normal (threshold number of noise dots tolerated=63 in those born prematurely and 69 in controls, p>0.20). Thus, deficits in the processing of global form, global motion, and biological motion evident at 5 – 9 years of age for children born very prematurely appear to be a consequence of slower than normal development rather than a permanent outcome of prematurity. This pattern contrasts with our findings for cataract-reversal patients, in whom the deficits found during childhood appear permanent.

Acknowledgement: Canadian Institutes of Health Research (CIHR) Grant MOP 36430 and TMH-103145

Sunday PM

Development

Monday, May 19, 8:15 - 9:45 am
Talk Session, Talk Room 1
Moderator: Terri Lewis

41.11, *8:15 am* **Categorization of faces versus objects in the infant's right occipito-temporal cortex by means of fast periodic visual stimulation** Adelaide de Heering[1](adelaide.deheering@uclouvain.be), Goedele Van Belle[1], Bruno Rossion[1]; [1]Institute of Research in Psychology and Institute of Neuroscience, University of Louvain, Belgium.

Human adults are extremely efficient at detecting faces in complex visual scenes, being able to categorize a wide range of visual stimuli as faces and discriminate those from other visual categories accurately and rapidly (Crouzet et al., 2010; Rousselet et al., 2003). Yet the developmental course and the neural basis of this remarkable ability remain unknown. To clarify these issues, we performed EEG recording (32-channel) of 15 4- to 6-month-old infants viewing 20-second sequences of images flickering at 6 Hz (i.e., 6 images/second). A stimulation sequence contained repetitive series of 4 unsegmented pictures of objects (O) followed, every fifth stimulus, by a picture of a face (F) (Figure 1). Objects and faces were centred but varied substantially in size, colour, lighting and viewpoint, with faces varying also in gender, age, ethnical origin and expression. Infants performed between 5 to 12 trials (1 minute and 40 seconds to 4 minutes of experimentation). EEG trials were averaged for each infant separately and Fourier transformed into the frequency domain. A sharp response was found over the medial occipital lobe exactly at the base stimulation frequency (6 Hz) (averaged signal-to-noise ratio (SNR) at Oz: 8.87; Figure 2, left). More importantly, there was a distinct response at the oddball (face) frequency (1.2 Hz), particularly salient at the right occipito-temporal electrode P8 (averaged SNR at P8: 2.56; Figure 2, right). These findings have three implications: first, they show that 4- to 6-month-old infants discriminate faces from other complex non-face objects and generalize across faces despite their high physical variance. Second, they indicate that the right hemisphere advantage for face perception emerges early in infancy and is therefore independent of left lateralized letter/word representations emerging later during development. Finally, they highlight the power of fast periodic visual stimulation to characterize infants' high-level visual processes rapidly and objectively.

41.12, *8:30 am* **Early monocular enucleation selectively disrupts the development of neural mechanisms for face perception** Krista Kelly[1,2,3](kkelly@yorku.ca), Keyvan Tcherassen[1], Brenda Gallie[3], Jennifer Steeves[1,2,3]; [1]Department of Psychology, York University, Toronto, ON, Canada, [2]Centre for Vision Research, York University, Toronto, ON, Canada, [3]The Hospital for Sick Children, Toronto, ON, Canada

Background. Monocular enucleation (surgical removal of one eye) during infancy results in intact low- to mid-level spatial vision (see Kelly et al., 2013 for a review). A mild impairment is observed, however, for the higher-level spatial vision ability, face perception, compared to binocularly intact controls (Kelly et al., 2012). Nonetheless, house perception is intact, suggesting a face-specific deficit with early enucleation. Similar face deficits are observed in monocular deprivation from congenital cataract (Le Grand et al., 2003, 2004). Further, early monocular deprivation from amblyopia and strabismus decreases functional activation in face-selective brain regions, including the middle fusiform gyrus [fusiform face area (FFA)] and inferior occipital gyrus [occipital face area (OFA)] (Lerner et al., 2003, 2006). Here, we sought to determine if decreased functional activation in face-specific brain regions are also present following early monocular enucleation. Methods. Six adults who had one eye enucleated early in life due to retinoblastoma (cancer of the retina) were compared to eight age- and sex-matched binocular and monocular viewing controls. All participants were placed in a 3T scanner and viewed blocks of images of faces, places, and objects. Repetition detection was used to maintain attention. Whole brain analyses were conducted to locate face-selective regions (FFA, OFA), and place-selective regions [parrahippocampal region (PPA), transverse occipital sulcus (TOS)] were used as a control comparison. Results. The early monocular enucleation group exhibited reduced activation in face-selective, but not place-selective, regions compared to controls. Conclusions. Our data are consistent with the previously reported behavioural face perception impairment. These findings suggest that although low- to mid-level spatial vision is intact, a lack of binocularity from early monocular enucleation specifically disrupts the behavioural and neural development of face perception, but not other forms of higher-level image category processing.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada (NSERC), Canada Foundation for Innovation, The Banting Research Foundation

41.13, *8:45 am* **Cortical Timing, Early Attention, and Functional Vision in Infants with Perinatal Brain Injury** Oliver Braddick[1](oliver.braddick@psy.ox.ac.uk), Janette Atkinson[2], Morag Andrew[3], Christine Montague-Johnson[3], Jin Lee[1], John Wattam-Bell[2], Jeremy Parr[4], Peter Sullivan[3]; [1]Experimental Psychology, University of Oxford, [2]Developmental Science, University College London, [3]Paediatrics, University of Oxford, [4]Inst of Neuroscience, Newcastle University

Visual and visuocognitive measures potentially provide sensitive early indicators of brain development in children at risk from perinatal brain injury (PBI). Here we report findings from the 'Dolphin' trial of preterm and term-born infants with PBI graded on MRI as 1 (normal/mild), 2 (moderate), or 3 (severe). Infants were tested 3-4 times between 0-24 months, using two VERP latency measures, fixation shifts (FS) to detect early attention deficits, and the ABCDEFV functional vision battery (Atkinson et al, 2002). VERPs were recorded in 57 PBI infants for a contrast reversing grating (2-8 reversals/sec). Latency measures from (a) the transient P1 peak at 2 r/sec; (b) the gradient of steady-state phase against frequency ('calculated'), were compared with typically developing infants (Lee et al ,2012). Transient latencies in most PBI and all typically developing infants reached adult levels around 100 ms by age 4-5 months. In contrast, calculated latency, which in typical development asymptotes to adult levels before age 1 year, averaged over 200 ms for PBI infants. The calculated measure, reflecting the time course of cortical processing beyond initial activation of V1, is thus more sensitive to cerebral impairment. On FS, 33 PBI infants, tested between 4-8 months post-term age, made significantly more errors and longer latencies to shift attention, with performance worsening across PBI severity, compared to typically developing infants (Atkinson & Braddick, 2012). These attention deficits in PBI infants , which reflect poor cortical control, were more marked when the initially centrally fixated target remained visible when the second peripheral target appeared ('competition'). On the ABCDEFV many PBI infants showed deficits particularly on visuo-motor, visual field and spatial tasks related to dorsal stream function. We will discuss the relation of VERP latencies, attentional performance, and functional vision tasks to developing brain mechanisms and their remediation in PBI.

Acknowledgement: Castang Foundation, Nutricia, Leverhulme Trust

41.14, *9:00 am* **Coarse stereopsis reveals residual binocular function in children with strabismus** Kimberly Meier[1](kmeier@psych.ubc.ca), Grace Qiao[2], Laurie M. Wilcox[3], Deborah Giaschi[2]; [1]Department of Psychology, University of British Columbia, [2]Department of Ophthalmology and Visual Sciences, University of British Columbia, [3]Department of Psychology, Centre for Vision Research, York University

Depth information can be extracted from small retinal disparities (fine stereopsis), or large disparities that give rise to diplopia (coarse stereopsis). Stereopsis for large disparities may be spared when stereopsis for small disparities is disrupted by amblyopia, possibly due to the early development of coarse stereopsis (Giaschi et al. 2013, J Vision). Here we extend these findings to include children with strabismus alone with no confounding visual acuity deficits. Further, we evaluate the link between stereopsis and eye alignment following strabismus surgery. Stereoscopic stimuli were presented using liquid crystal shutter glasses to children (4-12 years) with poor stereoacuity due to strabismus or strabismic amblyopia. The task was to indicate whether a cartoon character was nearer or farther than a zero-disparity reference frame. Test disparities were categorized as fine (0.02, 0.08, 0.17, 0.33, 0.67, 1.0 degrees) or coarse (2.0, 2.5, 3.0, 3.5 degrees) based on a preliminary diplopia assessment. A subset of children had undergone strabismus surgery and a retrospective chart review was performed to classify them as eyes-straight or eyes-misaligned, based on eye alignment one year post-surgery. Performance was similar in both groups of children, and matched that previously obtained from anisometropic and mixed amblyopia groups. In the coarse range, all groups of stereodeficient children were statistically indistinguishable from age-matched control children. However, the stereodeficient children showed significantly degraded performance in the fine range. Accuracy was higher in the eyes-straight group than in the eyes-misaligned group, particularly in the coarse range. Our results add to growing evidence that coarse stereopsis may be spared when fine stereopsis is disrupted, in this case from early visual deprivation due to strabismus. We propose that the coarse stereoscopic mechanism acts to keep the eyes aligned following surgery, and that it plays essentially the same role in the typical development of coordinated binocular eye movements.

Acknowledgement: Canadian Institutes of Health Research

41.15, *9:15 am* **Over-specific perceptual learning in ASD** Hila Harris[1](hila.harris@weizmann.ac.il), Ryan Egan[2], Akshat Gupta[2], Nancy Minshew[3], Yoram Bonneh[1,4], David J. Heeger[5], Dov Sagi[1], Marlene Behrmann[2]; [1]Department of Neurobiology/Brain Research, Weizmann Institute of Science, Rehovot, Israel, [2]Department of Psychology, Carnegie Mellon University, Pittsburgh, PA, [3]Center for Excellence in Autism Research, University of Pittsburgh, Pittsburgh, PA , [4]Department of Human Biology, University of Haifa, Israel, [5]Department of Psychology and Center for Neural Science, New York University, New York, NY

Autism spectrum disorder (ASD) is a neurodevelopmental disorder in which, in addition to social interaction and communication impairments, there are often sensory alterations. Much remains to be learned regarding the mechanisms governing sensory plasticity in ASD. Here, we do so using modulated levels of sensory adaptation. In non-ASD adults, repetitions are associated with specificity of visual learning and reduce sensory sensitivity due to adaptation. Individuals with ASD commonly require repetitive training for learning and the consequences of this are unknown. ASD adult individuals (N=11) and controls were trained with the same standard texture discrimination task (backward masked, randomized SOA) for 4 days (Harris, Gliksberg, Sagi; Curr. Biol.2012). Transfer was tested on day 5 by switching the target's location. The ability to learn at the new location was examined on days 6-8. In each group, half of the observers were trained with fixed target trials, termed standard training ('standard'), while the other half received added task-irrelevant trials ('dummy'), which are known to reduce adaptation and lead to transfer of learning in non–ASD subjects. Results showed that training with dummy trials facilitates learning and its transfer in ASD and non-ASD observers. Also, both ASD and non-ASD 'standard' observers showed negligible learning and specificity of learning. Most importantly, at the transfer location, unlike non–ASD observers who always learn at the new target location, ASD observers did not improve, reaching thresholds levels comparable to day1. Our results suggest that visual perceptual learning in ASD matches that of non-ASD observers. However, while non-ASD observers learn at the transfer location, ASD learning was over-specific and affected subsequent generalization. Reducing sensory adaptation positively impacts ASD observers, enabling enhanced learning and further generalization of learning. Together, these findings elucidate key properties of perceptual learning in ASD and offer guidance for future intervention.

Acknowledgement: This work was supported by grants from the US-Israel Binational Science Foundation and the Simons Foundation. H.H. thank the Azrieli Foundation for the award of an Azrieli Fellowship.

41.16, *9:30 am* **Ensemble perception of size in 4-5 year-old children** Timothy Sweeny[1](timothy.sweeny@du.edu), Nicole Wurnitsch[2], Sophie Bridgers[2], Alison Gopnik[2], David Whitney[2,3]; [1]Department of Psychology, University of Denver, [2]Department of Psychology, University of California, Berkeley, [3]Vision Science Group, University of California, Berkeley

Groups are nearly everywhere we look, but our ability to perceive them is anything but commonplace. Attention and memory have limited capacity, only allowing us to perceive and remember precise information about a few things at a time. To overcome these bottlenecks, the visual system engages a mechanism known as ensemble coding, in which noisy information about many items is condensed into a single representation that summarizes the group. This direct representation allows adults to appreciate the gist at little computational cost. Without it, the scope of our visual experience would be severely impoverished. Given the importance of ensemble coding, it is surprising how little is known about its development. While children can perceive basic properties of homogeneous groups, like numerosity, it is unclear if they possess the sophisticated ensemble algorithms necessary to summarize properties of heterogeneous groups, like average size. Here, we show that 4-5 year-old children do engage such summary mechanisms. Children viewed two groups of oranges or just a pair of oranges, all with a variety of sizes. When evaluating which group had the larger oranges overall, children integrated and averaged the sizes of multiple oranges, producing percepts of groups nearly as precise as those of single oranges. This pooling was independent of numerosity, continuous extent, density, and contrast. While sensitive, an ideal observer analysis showed that children integrated fewer oranges into their ensemble representations than adults. And with brief presentations, children engaged group perception with limited flexibility—those who excelled at ensemble coding were the worst at discriminating single oranges, and vice versa. Our findings provide a novel view of ensemble coding as it develops. More generally, they reveal new insights into the way children see and understand their environment, and they illustrate the fundamental nature of ensemble coding in visual perception.

Acknowledgement: National Institutes of Health grant R01 EY018216 and the National Science Foundation grant NSF 0748689

Attention: Spatial

Monday, May 19, 8:15 - 9:45 am
Talk Session, Talk Room 2
Moderator: Antoine Barbot

41.21, *8:15 am* **Proactive spatial inhibition in visual selection** Donatas Jonikaitis[1], Saurabh Dhawan[1], Heiner Deubel[1]; [1]Department of Psychology, Ludwig-Maximilians-Universität München, Germany

Inhibitory mechanisms have long been hypothesized to operate in parallel with facilitatory mechanisms in selection of information. However, visual selection has predominantly been studied in the context of signal enhancement at specific locations. We investigated whether active and task-dependent (as opposed to reflexive) inhibition of specific locations can be used as a complementary strategy in visuo-spatial tasks. We used a delayed match- or nonmatch-to- sample task in which a cued location has to be memorized either to plan a saccade to it or to avoid making a saccade to it, respectively. We found that while marking a location as a future saccade target, expectedly, resulted in a spatial selection benefit at that location, marking it as forbidden to saccades led to a cost in spatial selection specific to that location. We further show that, first, the spatiotemporal dynamics of these amplificatory and inhibitory effects were characteristically different from each other. Second, this spatial cost could be sustained over long task delays, which to our knowledge, is the first demonstration of the capacity to sustain spatially selective inhibition. Third, detection of pop-out visual search targets at the inhibited location was found to be impaired, showing that the observed inhibitory effects were mediated by biased selection at early stages of visual information processing. Our results suggest that like selective attention, selective spatial inhibition is an active visual mechanism that can be called into play to subserve visual and response selection requirements.

41.22, *8:30 am* **Attentional modulation is weak in V1 in human amblyopia** Chuan Hou[1](chuanhou@ski.org), Kim Yee-Joon[1], Preeti Preeti Verghese[1]; [1]Smith-Kettlewell Eye Research Institute

It is well known that attention affects perception and selects informative neural populations as early as V1. However, it is not clear whether attentional modulation is affected by amblyopia. Here we used source-imaged steady-state visual evoked potentials (SSVEPs), to determine whether this is the case. Our stimulus design is essentially identical to the one used by Lauritzen et al (2010). We presented two 8 deg gratings, flickering at 12.5 and 16.7, with centers 7 deg to the left and right of fixation, respectively. Amblyopic observers fixated centrally and viewed the display monocularly while targets were presented bilaterally. A cue indicated that the observer should attend to left or right to detect a contrast increment on the cued grating. We recorded evoked responses at the second harmonic of the driving frequencies. Our data show that the modulation of the evoked response due to attention is different in amblyopic observers compared to observers with normal vision. Both eyes of amblyopic observers showed no attentional modulation in area hMT+, where previous studies showed strong attentional modulation in normal vision observers (Lauritzen et al., 2010). Morevoer, the pattern of attentional modulation was different between amblyopic and non-amblyopic eyes. The non-amblyopic eye showed attentional modulation in areas V1 and V4, while the amblyopic eye only showed attentional modulation in area V4, but not in V1. These findings indicate that the attentional modulation in V1 is strongly affected by amblyopia, even though the non-amblyopic eye shows clear attentional modulation in early visual areas.

Acknowledgement: Smith-Kettlewell Eye Research Institute, Pacific Vision Foundation

 See page 3 for Abstract Numbering System

41.23, *8:45 am* **Spatial and feature-based attention differentially affect the gain and tuning of orientation-selective filters** Antoine Barbot[1](antoine.barbot@nyu.edu), Valentin Wyart[2], Marisa Carrasco[1,3]; [1]Psychology Department, New York University, [2]Institut National de la Sante et de la Recherche Medicale, Department des Etudes Cognitives, Ecole Normale Superieure, Paris, France, [3]Center for Neural Science, New York University

Background: Spatial and feature-based attention improve performance in contrast sensitivity tasks. Two mechanisms have been proposed to explain how attention affects visual responses: gain and tuning changes. Some studies indicate that spatial attention only affects the gain of the population response, whereas feature-based attention affects both the gain and tuning. Here, we directly assessed the influences of spatial and feature-based attention on the gain and tuning of orientation-selective responses. Using a reverse-correlation technique, we quantified how signal-like fluctuations in stimulus energy predict trial-to-trial variability in participants' judgments, and investigated how both types of attention affect the energy sensitivity of orientation-selective filters. Procedure: Two noise patches were presented to the left and right of fixation. Each patch could contain a Gabor signal embedded in Gaussian noise. When present (50% of the trials), the signal could be vertical or horizontal. At the beginning of each trial, an informative (66% valid) central pre-cue indicated the relevant location (spatial) as well as the signal orientation (feature-based). To eliminate location and feature uncertainty, a post-cue indicated the target location as well as its orientation (for both present and absent trials). We used a reverse-correlation technique to quantify how both types of attention affect the energy sensitivity profile of orientation-selective filters. Results: Spatial and feature-based attention improved performance (d') in an additive and independent way. Moreover, both types of attention increased the energy sensitivity of orientation-selective filters, but in dissociable ways. Whereas spatial attention only increased the gain, feature-based attention increased the gain and sharpened the tuning of orientation-selective filters. Conclusion: Using reverse-correlation, we provide direct evidence regarding how spatial and feature-based attention affect the gain and tuning of orientation-selective filters. These findings help narrow the gap between perception and known neurophysiological effects, and further our understanding of how attention improves contrast sensitivity.
Acknowledgement: NIH RO1 EY16200 to MC

41.24, *9:00 am* **The Mere Exposure Effect Is Modulated By Selective Attention But Not Visual Awareness** Yu-feng Huang[1](yufeng.huang@duke-nus.edu.sg), Po-jang Hsieh[1]; [1]Neuroscience and Behavioral Disorders Program, Duke-NUS Graduate Medical School

Repeated exposures to an object will lead to an enhancement of evaluation toward that object. Although this mere exposure effect (MEE) may occur when the objects are presented subliminally, the role of conscious perception per se on evaluation has never been examined. Here we use a binocular rivalry paradigm to investigate whether variance in conscious perceptual duration of faces has an effect on their subsequent evaluation, and how selective attention and memory interact with this effect. Participants first performed a binocular rivalry task consisting of a free rivalry block and an attending block. In the free rivalry block, two faces were projected individually to left and right eye to produce rivalry experience and participants were required to report the dominant percept. In the attending task, the stimulus configuration was identical to those in the free rivalry block, except that participants were instructed to attend to one of each pair of faces. After the binocular rivalry phase, participants performed an unexpected evaluation and recall task, which were consisted of novel and previously presented faces. Replicating MEE, the results showed that previously exposed faces were more positively evaluated than novel faces. Furthermore, variance in conscious perceptual duration of the faces did not affect evaluation, whereas attended faces were better evaluated than the non-attended faces. Finally, this effect is not due to attended faces were better memorized because subjects could not recall which face had been attended to. Collectively, our finding suggests that MEE can be modulated by selective attention but not visual awareness.

41.25, *9:15 am* **Serial allocation of visual attention in extrastriate cortex during simultaneous monitoring of multiple locations: a time-resolved fMRI study** Paige Scalf[1](pscalf@email.arizona.edu), Elexa St. John-Salltink[2], Markus Barth[2], Hawkwan Lau[3], Floris De Lange[2]; [1]Department of Psychology, University of Arizona, [2]Ctr. for Cognitive Neuroimaging, Donders Inst., Nijmegen, Netherlands, [3]Psychology, Columbia Univ., New York City, NY

When directed to multiple spatial locations, attention has traditionally been believed to be simultaneously distributed among them. Rhythmic presentation of spatially disjoint targets at optimal frequencies improves their detection, however, suggesting that covert attention may in fact be rapidly cycled among attended locations. This work has relied on behavioral measures of target detection to assess the location of visual attention at any given time. Such findings may indeed reflect the serial allocation of attention during attentional search, but may also reflect a serial limitation on the ability to encode target items such that they are available for report. We used highly time-resolved fMRI (TR = 88 ms) to investigate whether directing attention to multiple items results in serial rather than simultaneous enhancement of their representations in visual cortex. Critically, we examined only trials in which behavioral targets were not present; any "serial" timing effects observed under these conditions necessarily reflect serial allocation of attention rather than serial target encoding. We measured extrastriate signal evoked by stimuli in the four quadrants under three conditions. A simultaneous, 400 ms, 25% increase in luminance of all four items served as a model for simultaneously distributed attention. A sequential, 100 ms, 100% increase in luminance for each item served as a model for sequentially allocated attention. We compared these with an attended condition, in which participants monitored the four items (whose luminance did not change). Although the peak of the evoked BOLD response did not change significantly across visual fields under simultaneous stimulation ($p = .22$), it did change significantly across the visual field under sequential stimulation ($p=.04$) and attended conditions ($p = .04$). The results undermine the notion that attention may be simultaneously diffused across multiple items; instead, attended items appear to undergo serial sampling.

41.26, *9:30 am* **Kalman filter models of multiple-object tracking within an attentional window** Sheng-hua Zhong[1](szhong2@jhu.edu), Zheng Ma[1], Colin Wilson[2], Jonathan Flombaum[1]; [1]Department of Psychological and Brain Sciences, Johns Hopkins University, [2]Department of Cognitive Science, Johns Hopkins University

Multiple-object tracking has been an influential paradigm for evaluating attention and working memory limits. Recent work has made the consequences of these limits concrete, employing the Kalman filter—a Bayesian state estimator—as a computational model, and demonstrating how noisy estimates of position lead to target/nontarget confusions. Moreover, they have accounted for declining performance with increasing load by assuming that noise in spatial estimates is regulated by limited resources. But these models have also been unrealistic in several ways that we investigated in a series of computational and behavioral experiments. First, extant models sample at the frame rate of presentation. In an experiment with a tracking load of one, we found that models with fast sampling rates (>20Hz) overestimate human performance at high speeds. Second, extant models track all items including nontargets (labeling the targets). This leverages mutual exclusivity to make identity decisions. But it belies the assumption that limited resources impair estimation; if all items are tracked regardless, why does the number of targets matter? When we contrasted target-only and track-all models, the latter did a worse job of accounting for human performance in several ways, including by overestimating performance for tracking with different target loads. Finally, we investigated the possibility that an attentional window might supply an opportunity for mutually exclusive but local identity assignments. We implemented a model that tracked other items only within a limited window surrounding each target. Performance improved considerably compared to no-window models, and fits to human results also improved. Overall, models with limited sampling rates and attentional windows supply a better and more intuitive account of human MOT performance. They also illuminate a wider range of opportunities for a resource-limited observer to respond to load demands, including the control of sampling rate and the scope of attentional selection.

Visual search

Monday, May 19, 10:45 am - 12:15 pm
Talk Session, Talk Room 1
Moderator: Krista A. Ehinger

42.11, *10:45 am* **Foraging and navigating in a virtual orchard: Which tree do you visit next?** Krista A. Ehinger[1,2](kehinger@mit.edu), Jeremy M. Wolfe[1,2]; [1]Brigham & Women's Hospital, [2]Harvard Medical School

Real-world foraging tasks are multilayered: you search for the best apple on the tree and for the best tree in the orchard. How do you decide where to go to maximize your search returns? We ran foraging experiments in a 3D virtual orchard, where participants were asked to pick as many "good" apples as possible within a time limit. In Experiment 1, "good" apples were red and "bad" apples were yellow; in Experiment 2, good and bad apples were drawn from overlapping color distributions. In both cases, we were interested in how foragers would decide which tree to visit next. We compared two naïve foraging rules (always go to the nearest tree, or the one with the most red apples) to an optimal foraging model, which assumes that people maximize their rate of return by choosing the tree(s) with the best fruit to distance ratio. Furthermore, we asked whether observers only thought one step ahead, choosing the single tree that gave the best return? Or, alternatively, did they think ahead and look for multi-tree paths that gave the best overall return? We modeled these alternatives by computing the rate of return for every tree (or every path) and then investigated how well human performance matched the predictions of these models. Results from the two experiments were very similar: all versions of optimal foraging better predicted human behavior than the naïve "nearest tree" rules. Moreover, the "best 2-step path" model (AUC = 0.94) modestly outperformed the 1-step ("best tree") model (AUC = 0.92). The 3-step model's performance was not significantly different from the 2-step model. These results show that people use an optimal foraging strategy in a 3D environment and they "think ahead," choosing the best available path between multiple trees, rather than merely choosing the best single tree.

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42.12, *11:00 am* **The Long and the Short of Intertrial Priming** Wouter Kruijne[1](w.kruijne@gmail.com), Martijn Meeter[1]; [1]Vrije Universiteit Amsterdam

Attending and processing stimuli on one trial can facilitate processing of stimuli with the same features on the next trial, a phenomenon termed intertrial priming. Few accounts that explain priming mechanistically have been proposed yet, but one theory proposes that episodic retrieval of past trials has a crucial role. Using an established model of episodic LTM, we were indeed able to reproduce various findings from the priming literature. However, the general principles of learning embedded in the model yielded a counterintuitive prediction: a block with a surplus of trials in which the target has, for example, a certain color (a bias block), will result in long-term priming, speeding search for such targets for the remainder of the experiment. Testing this prediction, we found a remarkable dissociation between singleton- and conjunction search: No long-term learning effects were found for singleton search, but for conjunction search we found that bias blocks affected search in later unbiased blocks, without obvious forgetting. Further experiments clearly illustrated this effect could be ascribed to long-term memory mechanisms, as long-term priming persisted after an intervening week. Furthermore, this long-term priming effect did not seem to result from an explicit strategy recruited by the participants and occurred on top of short-term intertrial priming. Based on these findings, and findings from neurophysiology, we propose to dissociate priming effects found in singleton and conjunction search, and illustrate how priming may fractionate in short- and long-term effects through separate mechanisms.

42.13, *11:15 am* **Facilitation of visual search from object-to-scene binding in an immersive virtual environment** Chia-Ling Li[1](sariel.cl.li@utexas.edu), M Pilar Aivar[2], Dmitry M Kit[3], Matthew H Tong[4], Mary M Hayhoe[4]; [1]The Institute of Neuroscience, University of Texas at Austin, [2]Department of Psychology, Universidad Autónoma de Madrid, [3]Department of Computer Science, University of Bath, [4]Center for Perceptual Systems, University of Texas at Austin

In a familiar environment, memory representations may reduce attentional demands for visual information to guide behavior. Despite earlier evidence for sparse memory representations of complex scenes, more recent evidence has revealed the existence of more extensive memory representations (Castelhano & Henderson, 2007; Hollingworth, 2009). Experiments using 2D images have shown that visual search is facilitated by a scene preview, whether or not future search targets are present, suggesting that both memory for context and object-to-scene binding facilitate visual search in 2D images. However, memory representations during ongoing daily behaviors in the real world are a consequence of a very different exposure history than in typical experiments. In this study we examined visual search in an immersive virtual environment to determine (1) whether pre-exposure to the scene context and targets play a role in visual search, and (2) what aspects of the context might benefit visual search. The virtual environment was composed of two rooms; one room was explored for 1 minute before the search trials while the other was not. Early search targets were geometric objects, while later trials featured previously present realistic apartment objects. Pre-exposure to one of the rooms facilitated search for geometric objects (by approximately 25%), but only when the targets were present during exploration and only during early searches. When apartment objects are continuously visible, with opportunities for incidental fixations, further experience in the environment led to small search facilitation for those objects nearby previous targets. However, there was no facilitation for more distant objects despite having been present in the environment for over 5 minutes of immersive experience. Together the results suggest that prior exposure in immersive 3D environments leads to a small advantage in subsequent search but only when future search targets are also present, and the primary determinant of search time is context-relevant experience.

42.14, *11:30 am* **The influence of task set and task switching on visual behavior** Michael Dodd[1](mdodd2@unl.edu), Mark Mills[1], Edwin Dalmaijer[2], Stefan Van der Stigchel[2]; [1]Department of Psychology, University of Nebraska - Lincoln, [2]Experimental Psychology, Utrecht University

The study of task-switching has a rich history (Monsell, 2003) but has been surprisingly overlooked as it relates to vision. Task-switching studies primarily focus on executive function relating to maximizing performance benefits while minimizing costs. When task-switching has been applied to vision it is usually to investigate the executive function required to switch back and forth between prosaccades and antisaccades as opposed to the influence of a task switch on visual behavior per se. Critically, recent examinations of task set and visual behavior have demonstrated differences in the influence of memory on attentional allocation and the spatial and temporal characteristics of oculomotor kinematics (Dodd et al., 2009; Mills et al., 2011). For example, inhibition-of-return (IOR: slowed responding at previously fixated locations) is observed in search tasks whereas facilitation-of-return (FOR: speeded response at previously fixated location) is observed in non-search tasks. In the present series of four experiments, we examine the influence of task set and task switching on IOR/FOR and oculomotor kinematics (e.g., saccade amplitude, fixation duration). Participants view scenes while either searching for a target (embedded N or Z), memorizing the scene, or evaluating the scene, with task set being either blocked or mixed. Search type is also manipulated between experiments. Both task set and task switching lead to substantial behavioral changes in oculomotor kinematics, with the most surprising changes relating to IOR/FOR. Whereas IOR is observed during search when task set is blocked, replicating previous findings, when task set is mixed, IOR is only observed during search when the previous trial also required a search. If preceded by a different task set, FOR is observed during search. These experiments provide important insight into the costs and benefits associated with task switching as it relates to visual behavior, in addition to demonstrating the flexibility of the visual system.

Acknowledgement: This research has been supported by the NIH grant R01EY022974

42.15, *11:45 am* **Integration of visual features over time: Behavior and brain activity** Sebastian Frank[1](sebastian.m.frank.gr@dartmouth.edu), Eric Reavis[1], Mark Greenlee[2], Peter Tse[1]; [1]Department of Psychological and Brain Sciences, Dartmouth College, [2]Institute for Experimental Psychology, University of Regensburg

People can learn arbitrary visual feature conjunctions when the features to be conjoined are present at the same time. This learning is associated with increasing activity in visual cortex (Frank et al., 2013, Human Brain Mapping). Can people also integrate temporally non-coincident features into a coherent conjunction that spans space and time? If so, what brain areas are involved in spatio-temporal conjunction learning? We addressed these questions by training participants to search for a single dot moving down, then up, amongst distractor dots moving up, then down presented in an eccentric radial array. Twenty participants performed the visual search task during an MRI scan, then completed ten days of practice on the task, after which they performed the task in the scanner again. With training, target detectability increased, as measured by d'. At the same time reaction time decreased dramatically. The difference in BOLD signal between target present vs. target absent trials increased in higher-order visual motion

Monday AM

areas MST and MT, but not in retinotopic cortex. This activation difference in MST and MT was significantly correlated with learning rate: participants who learned quickly had a larger signal difference after training than those who learned slowly. In retinotopic visual cortex, target locations showed more BOLD activity than distractor locations after learning, but this increase in BOLD signal-to-noise was not correlated with learning rate.

42.16, *12:00 pm* **The handoff of the attentional template from working memory after repeated search: The effects of task difficulty** Eren Gunseli[1](e.gunseli@vu.nl), Christian N.L. Olivers[1], Martijn Meeter[1]; [1]Department of Cognitive Psychology, VU University, Amsterdam

Prominent theories of attention claim that visual search is guided through attentional templates stored in working memory. Recently, the contralateral delay activity (CDA), an electrophysiological index of working memory storage, has been found to rapidly diminish when observers repeatedly search for the same target, suggesting that, with learning, the template moves out of working memory. However, this has only been investigated for pop-out search for a distinct color target, for which a strong top-down attentional guidance is not necessary. We hypothesized that more effortful search tasks, in which there is no guidance from a distinct color, might rely, to a greater extent, on an active attentional template in working memory. This would predict a slower handoff to long term memory, and thus a slower decline of the CDA. Using ERPs, we compared the rate of learning of attentional templates in pop-out and effortful search tasks. Unexpectedly, the rate of learning an attentional template, as indexed by the rate of decrease in the CDA, was the same for both search tasks. Similar results were found for a second component indexing working memory activity, the late positive complex, or LPC. However, the LPC was also sensitive to anticipated search difficulty, as was expressed in a greater amplitude prior to the harder search task. We conclude that the amount of working memory activity invested in maintaining an attentional template, but not the rate of learning, depends on search difficulty.

Acknowledgement: Nederlandse organisatie voor Wetenschappelijk Onderzoek (The Netherlands Organisation for Scientific Research

Object recognition: Neural mechanisms 1

Monday, May 19, 10:45 am - 12:15 pm
Talk Session, Talk Room 2
Moderator: Reza Rajimehr

42.21, *10:45 am* **Novel module formation reveals underlying shape bias in primate infero-temporal cortex** Krishna Srihasam[1](krishna_srihasam@hms.harvard.edu), Margaret Livingstone[1]; [1]Department of Neurobiology Harvard Medical School, Boston, MA, [2]Department of Neurobiology Harvard Medical School, Boston, MA

Six juvenile monkeys were trained intensively to choose between pairs of symbols using in-cage touch-screens. We trained the monkeys on three separate symbol sets: alphanumeric symbols, tetris shapes and cartoon faces; training for each set took about 8 months. Within a set each symbol represented a unique reward amount from 0 to 25 drops. Groups of monkeys learned the 3 sets in different order. Before and after learning each set, the monkeys were scanned while they viewed blocks of the trained symbol set, control shapes, and monkey faces. After training on each symbol set, we found areas in inferior temporal cortex that were selectively more active for the trained shapes than for controls of the trained set. The locations of these newly specialized domains were consistent across monkeys and did not depend on the order the symbol sets were learned. Within each monkey, the patch of cortex that was selectively more active to trained cartoon faces was just ventral to the middle face patch; the selectivity to tetris symbols was just ventral to that, and the patch selective to alphanumeric symbols was the most ventral of the 3, and was located in the same place as previously reported scene-selectivity1. The fact that these domains consistently map to characteristic locations suggest that whatever region will become specialized in response to intensive experience of some particular set of shapes depends on the shape and indicates a pre-existing shape organization. Tootell and colleagues2 have suggested that this organization is based on curvature; such an organization is consistent with what we find. (1) Kornblith, S., Cheng, X., Ohayon, S. & Tsao, D.Y. Neuron 79, 766-781 (2013) (2) Tootell, R.B.H., Nasr, S. & Yue, X. Soc. Neurosci. Abstr., 624.604 (2012)

Acknowledgement: NIH-EY16187 and Nancy Lurie Marks Research Fellowship in Autism

42.22, *11:00 am* **Locally-Optimized Inter-Subject Alignment of Functional Cortical Regions** Marius Cătălin Iordan[1](mci@stanford.edu), Armand Joulin[1], Diane M. Beck[2], Li Fei-Fei[1]; [1]Department of Computer Science, Stanford University, [2]Beckman Institute and Department of Psychology, University of Illinois at Urbana-Champaign

Inter-subject cortical registration is necessary in functional imaging (fMRI) studies for making inferences about equivalent brain function across a population. Most state-of-the-art alignment methods attempt to preserve anatomical landmarks, cortical curvature, or functional connectivity between cortical volumes (Yeo, 2010; Sabuncu, 2010; Conroy, 2013). However, these methods have difficulty aligning high-level visual areas across subjects, mainly due to large variability in anatomical position. Consequently, we propose a locally optimized registration method that directly predicts the location of a seed region of interest (ROI) on a separate target cortical sheet by maximizing the correlation between voxel-level functional responses in the two maps. A key advantage of our method is allowing for non-smooth local deformations in the mapping. We reason that peak functional contrast points (where ROIs are centered) share similar function between subjects, yet functional gradients of selectivity surrounding the peaks may not be spatially organized identically across subjects (Huth, 2012). We test our method by aligning a difficult to match, functionally defined, object-selective ROI (lateral occipital complex, LOC) between subjects using a passive-viewing fMRI experiment where participants were shown 1,024 images of objects from 32 categories. Our method vastly outperforms two canonical baselines (anatomical-landmark-based AFNI alignment and cortical-curvature-based FreeSurfer alignment) in overlap percentage between predicted region and ground truth LOC (i.e. defined via standard localizer procedures): baselines 10-11%, ours 24%. Furthermore, our predicted maps are more consistent across subjects than both baselines (overlap of region commonly mapped from 3+ subjects: baselines 9-11%, ours 26%). Therefore, our technique improves the quality and reliability of matching and transferring the location of functional ROIs across subjects, an important step towards obviating the need for additional or impossible to obtain localizer scans. Moreover, our method can be used to investigate the complex relationship between anatomy, functional contrast peak (ground-truth ROI), and cortical computation (BOLD response).

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42.23, *11:15 am* **Functional parcellation of human visual cortex** Reza Rajimehr[1](rajimehr@mit.edu), Simon Kornblith[1], Robert Desimone[1]; [1]McGovern Institute for Brain Research, MIT

Characterizing the functional organization of visual cortex is a fundamental step in understanding how visual information is processed in the brain. Despite a century's effort to map visual cortical areas, there has been no comprehensive parcellation scheme for the entire visual cortex in the human brain. Here we used functional MRI and developed a data-driven approach to cluster occipito-temporal vertices of the cortical surface based on their responses to a 90-minute natural movie stimulus. To achieve an optimal clustering, the vertices were first represented in a lower-dimensional space using the principal component analysis (PCA), then a hierarchical clustering was applied in the PCA space. The hierarchical clustering enabled us to evaluate the macro-organization of visual cortex at different spatial scales. In all levels of hierarchical clustering, the functionally-defined clusters were remarkably organized on the cortical surface. In addition to all previously-known category-selective areas, the clustering revealed many spatially-localized regions in the occipito-temporal cortex. We characterized one specific region in the lateral temporal cortex ('area LT') that was selectively activated by object motion or body action in the movie. The cortical parcellation scheme presented here could guide subsequent studies in defining the functional properties of many new cortical areas.

42.24, *11:30 am* **Intermediate human visual areas represent the locations of silhouette edges in natural movies** Mark D. Lescroart[1], Shinji Nishimoto[2], Jack L. Gallant[1]; [1]Helen Wills Neuroscience Institute, University of California, Berkeley, [2]National Institute of Information and Communications Technology, Osaka, Japan

Intermediate visual areas (V4 and areas in lateral occipital cortex) respond selectively to variation in color, texture, motion, and shape. One goal of vision research is to make computational models that can predict responses to arbitrary stimuli varying in all these dimensions. However, most studies of these areas have only examined one or two dimensions in isolation. Therefore, the information that these areas represent about complex natural scenes is poorly understood. To address this issue we created a novel set of computer-generated movies to use as stimuli in a voxel-wise modeling fMRI experiment. The movies contained realistic objects in random settings, with naturalistic variation in color, texture, lighting, and camera motion. We quantified two stimulus parameters, silhouette edges and motion energy, by using meta-information from the rendering software and a spatiotemporal Gabor wavelet model (Nishimoto et al 2011). Because the locations of silhouette edges were often correlated with high contrast in motion energy when the camera moved in 3D, we also created a stimulus set containing only 2D motion. We used a 3T MRI scanner to record brain activity while subjects viewed both sets of rendered movies. We then used the silhouette edge and motion energy features and L2-regularized linear regression to fit voxel-wise models to the data from each individual subject. Finally, we used an independent data set to test predictions of the fit models. For the movies with 3D camera motion, the motion energy model gave better predictions than the silhouette model. However, for the movies that contained only 2D motion, the silhouette edge model gave better predictions in V4 and LO. Thus, although motion energy is correlated with the presence of silhouette edges in stimuli rendered using naturalistic camera motion, V4 and LO are best described by a model that explicitly represents the locations of silhouette edges.

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42.25, *11:45 am* **Spatial receptive fields persist at the latest stages of the human ventral visual stream** Kendrick Kay[1](kendrick@post.harvard.edu), Kevin Weiner[2], Kalanit Grill-Spector[2,3]; [1]Department of Psychology, Washington University in St. Louis, [2]Department of Psychology, Stanford University, [3]Stanford Neuroscience Institute, Stanford University

Recent fMRI studies using multivariate pattern analysis have demonstrated sensitivity to position and size in high-level regions of human visual cortex. While this indicates that information exists in these regions, the precise nature of this information remains unclear. Here we demonstrate a new protocol that quantitatively maps the population receptive fields (pRFs) of individual voxels in face-selective regions of human visual cortex. We measured BOLD responses while subjects viewed faces that varied systematically in position and size. Faces were positioned on a 7 x 7 grid (extending up to 3.0° eccentricity) and were presented at 3 different sizes (1.6°, 3.2°, 4.7° diameter). We then analyzed the BOLD responses measured at each voxel using a computational model that characterizes pRF position and size (Kay et al., J. Neurophys., 2013). We show that the model accurately accounts for responses in face-selective regions IOG-faces/OFA, pFus-faces/FFA-1, and mFus-faces/FFA-2. Importantly, the model successfully generalizes to novel untrained positions and sizes. Examining model parameters, we find systematic changes in pRF properties, including larger and more foveal pRFs in anterior face-selective regions. To investigate whether attention affects pRF properties, we repeated the measurements while subjects engaged in different tasks (maintaining fixation). We find that compared to a rapid serial visual presentation task at fixation, when a task is performed on the faces, pRFs in face-selective regions, but not in early visual areas, exhibit a response gain, increase in size, and shift away from the fovea. In summary, our results demonstrate that spatial pRFs persist at the latest stages of the ventral visual stream. Furthermore, our findings indicate that neural responses at these stages contain not only information about the content of a stimulus but also precise and systematic information about its spatial location.

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42.26, *12:00 pm* **Visual Field Coverage of Category-Selective Regions in Human Visual Cortex Estimated Using Population Receptive Field Mapping** Nathan Witthoft[1](witthoft@stanford.edu), Mai Nguyen[2], Golijeh Golarai[1], Alina Liberman[3], Karen F. LaRocque[1], Mary E. Smith[4], Kalanit Grill-Spector[1]; [1]Dept of Psychology, Stanford University, [2]Dept of Psychology, New York University, [3]Dept of Psychology, University of California, Berkeley, [4]Dept of Psychology, University of California, San Diego

Prior research on the position sensitivity of category selective regions has shown a coupling between face selectivity and foveal representations and place selectivity and sensitivity to the periphery (Levy 2001), as well as decreased tuning to position as one ascends the ventral stream hierarchy (Schwartzlose 2008). However, most studies have examined position sensitivity by comparing discrete locations in the visual field. We extend this prior work by using continuous retinotopic mapping and measuring population receptive fields (pRFs) in category selective regions. 12 subjects participated in an fMRI experiment that contained both a category localizer as well as retinotopic mapping using flickering checkerboard stimuli. By fitting a pRF model to each voxel, we determined the retinal position and the spatial extent of the visual field which best matched the observed BOLD response within each voxel. Then, in each individual brain we defined category-selective ROIs as well as visual field maps. Category-selective ROIs were subdivided by their intersection with visual field maps. Consistent with Aracaro et al 2009, place-selective voxels in the collateral sulcus overlap at least partially with the anterior ventral visual field maps (VO1-2; PHC1-2). pRF fits to these place-selective voxels show large receptive fields that have a strong bias towards the upper visual field and the periphery. By contrast, face-selective ROIs on the ventral surface (IOG-, pFus-, mFus-faces) did not overlap with known visual field maps, but contain pRFs that are foveally centered and their combined coverage of the visual field coverage is generally contained within the central 10°. Interestingly, pRFs in right hemisphere face selective ROIs show greater coverage of the ipsilateral visual field than those on the left, which may be related to the often-reported right hemisphere dominance for face processing in humans.

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3D Perception: Shape from X

Monday, May 19, 8:30 am - 12:30 pm
Poster Session, Jacaranda Hall

43.301 Seeing in Shadeworld

Edward Adelson[1,2], Phillip Isola[1,2]; [1]Dept. of Brain and Cognitive Sciences, MIT, [2]Computer Science and AI Lab, MIT

Shadeworld is an imaginary place populated with opaque surfaces that appear smoothly shaded. The real world is more complex, but Shadeworld contains some of the key properties that make images compelling. Scanning electron microscopy (SEM) images live in Shadeworld even though the math and physics is entirely unlike optical shading. The human visual system loves this kind of image, and microscopists have invented various other methods (e.g., freeze fracture and Nomarski) to provide pseudo-shaded images that are attractive and informative. Images of shaded (and pseudo-shaded) surfaces are generated by a rendering process (real or synthetic) that converts the 3D surface to a 2D image via some set of rules. There are many rules that yield a good sense of 3D; these can involve combinations of depth, surface normal, curvature, and other aspects of geometry. Phong shading is an example that is physically impossible but perceptually convincing. Ambient occlusion gives good shading by a very different process. It is remarkable that human vision is so successful at extracting 3D from such a variety of rendering conditions. We argue that the process of extracting 3D involves two estimation problems: (1) estimating the shape and (2) estimating the rendering process (and its parameters). Lambertian shading (estimate albedo and light direction) is famous but rarely occurs. The boundaries of Shadeworld are established by the characteristics of human shape perception. The most successful rendering processes have a kind of smoothness in the mapping between shape and luminance. In addition, the rendering parameters need to be fairly stable across an image, but not completely. We'll also describe some new methods for generating Shadeworld images using physical processes, which can be tailored for human vision, offering new approaches to light microscopy and surface analysis.

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43.302 The experimental bas-relief ambiguity

Maarten Wijntjes[1](m.w.a.wijntjes@tudelft.nl), Maciej Szaniawski[1], Sylvia Pont[1]; [1]Perceptual Intelligence lab, Industrial Design Engineering, Delft University of Technology

Literature on shape-from-shading (SFS) perception often claims that light and shape perception are intrinsically linked. Indeed, the classic convex/concave ambiguity can be solved when an observer assumes a (global) light direction. However, most studies only address 3D shape perception while ignoring illumination perception. This makes sense in the classical convex/concave ambiguity but in case of the more general bas-relief ambiguity, measuring both light and shape is paramount for making claims on the light-shape relation. We explored whether the formal relation between light and shape as described by Belhumeur et al. (1999) can be used to model human vision. To do so, we modeled bumpy spherical shapes that were 3D printed in three versions: compressed (40%, in the viewing direction), normal and stretched (140%). These flattened, spherical and oblong stimuli were presented in a lab setting where we could accurately manipulate the (collimated) light direction. Observers had to match the light direction of the real, illuminated 3D stimulus on a virtual illuminated sphere shown on a computer screen. Additionally, for each shape the perceived 3D geometry was measured by letting the observers adjust a virtual cross section of the stimulus. Overall, we found that although observers used both eyes (at about 1.5 m), the shapes were consistently misperceived as being spherical, despite their large physical variations. These erroneous shape perceptions could partly be traced back in their illumination settings, especially in the case of the flattened shape. However, we also found an unexpected large degree of variability in the illumination settings. To account for that we performed a control experiment on a smooth sphere, which revealed much smaller variability. Our data suggest that human vision can partly be modeled by the bas-relief ambiguity, and that observers are heavily biased towards globular shape inference.

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43.303 Limits on the estimation of shape from specular surfaces

Julia Mazzarella[1,2](jmazzare@skidmore.edu), Steven Cholewiak[1], Flip Phillips[2], Roland Fleming[1]; [1]Psychology, Justus-Liebig Universität, [2]Psychology and Neuroscience, Skidmore College

Humans are generally remarkably good at inferring 3D shape from distorted patterns of reflections on mirror-like objects (Fleming et al, 2004). However, there are conditions in which shape perception fails (complex planar reliefs under certain illuminations; Faisman and Langer, 2013). A good theory of shape perception should predict failures as well as successes of shape perception, so here we sought to map out systematically the conditions under which subjects fail to estimate shape from specular reflections and to understand why. To do this, we parametrically varied the spatial complexity (spatial frequency content) of both 3D relief and illumination, and measured under which conditions subjects could and could not infer shape. Specifically, we simulated surface reliefs with varying spatial frequency content and rendered them as perfect mirrors under spherical harmonic light probes with varying frequency content. Participants viewed the mirror-like surfaces and performed a depth-discrimination task. On each trial, the participants' task was to indicate which of two locations on the surface—selected randomly from a range of relative depth differences on the object's surface—was higher in depth. We mapped out performance as a function of both the relief and the lighting parameters. Results show that while participants were accurate within a given range for each manipulation, there also existed a range of spatial frequencies – namely very high and low frequencies – where participants could not estimate surface shape. Congruent with previous research, people were able to readily determine 3D shape using the information provided by specular reflections; however, performance was highly dependent upon surface and environment complexities. Image analysis reveals the specific conditions that subjects rely on to perform the task, explaining the pattern of errors.

43.304 Which pieces anchor the Shape-from-Shading puzzle and how they fit together

Benjamin Kunsberg[1](bkunsberg@gmail.com), Roland Fleming[2], Steven Zucker[3]; [1]Applied Mathematics Program, Yale University, [2]Department of Psychology, Justus Liebig University Giessen, [3]Department of Computer Science, Yale University

Although Shape-from-Shading (SFS) has been solved in unrealistic cases, there is a schism between computer vision techniques and neurobiological mechanisms. There is no neurobiological evidence for light-source representation in the early visual system, yet every SFS algorithm requires or estimates the light source position(s) prior to reconstruction of the surface. This is also contrary to psychophysical evidence, which shows accurate shape perception even with certain conflicting light sources or "weird shading," provided the shading flow remains stable. Thus, we investigate global SFS reconstruction using the shading flow and without knowledge of the light source. We derive mathematical results proving that the map relating shading to surface reduces in complexity at critical points of intensity, and these define pieces on which a global solution can be anchored. Psychophysical evidence illustrates this fact: shading is more important along the intensity critical points than on generic points. By applying light source invariant shading equations (presented previously at VSS) to critical points of image intensity, we are able to calculate the surface curvatures in select open neighborhoods (pieces) of the surface. However, the 3D orientation of each of these patches remains unconstrained. We thus derive compatibility equations based on the transport of the surface normal using the calculated curvatures. Under a relaxation-labeling scheme, we are able to select the correct orientation for each of the patches; thus we obtain a 3D proto-shape. This approximates the global solution and exhibits appropriate light-source invariance. Finally, we return to neuroscience. Our model is realized with a network of neurons tuned to different 3D orientations and curvatures. Recent work from Ed Connor's lab has found evidence for neurons of this kind in V4/IT. It is pleasing that the mathematics of shading inference mirrors the biology of connections.

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43.305 The perceptual matching of local surface orientation based on shape from shading

Eric Egan[1](egan.51@osu.edu), Christopher S. Kallie[1], James T. Todd[1]; [1]Psychology, The Ohio State University

The traditional approach for computing shape from shading is based on an assumption that the luminance in each local region is determined exclusively by its local orientation relative to the direction of illumination. In this study we utilized a new method for measuring observers' judgments of local surface orientation in order to test this assumption. Observers were shown the image of a 3D surface with a single probe region marked by a small red dot, and they were required to identify another point on the surface that had the same apparent local orientation. Our stimuli depicted a smoothly deformed planar surface at two different slants. Three different types of shading were employed, only one of which satisfied the assumptions of traditional models. On a given trial, a red dot was placed at a random location in a stimulus. A large dashed circle denoted a separate region that did not include the red dot but did include at least one location with the same orientation. Observers used the cursor to place a green dot within the circle at a location that appeared to have the same surface orientation as the location marked by the red dot. The results demonstrate that probe regions with the same apparent orientation may have quite different orientations on the actual depicted surface, and that the perceptually matched probe regions can have large differences in image intensity. This latter finding is incompatible with any algorithm for computing shape from shading that requires a known BRDF with a homogeneous pattern of illumination.

Acknowledgement: NSF grant BCS-0962119

43.306 Perception of Local Surface Patches Using Shape From Shading

Christopher S. Kallie[1](kallie.1@osu.edu), Eric Egan[1], James T. Todd[1]; [1]Psychology, Ohio State University

In 1980, Koenderink and van Doorn described a novel idea for representing surfaces, which is based on an inventory of qualitatively distinct patches. These shape categories include dimples, bells, furrows, humps and saddles. The goal of this study was to test whether observers can categorize smooth surface patches based on their parametrically defined categorical features under a wide range of conditions. Method: Parametric surfaces were generated using Gaussian distribution primitives that were projected onto ellipsoids, creating smooth, continuous local patches representing furrows, dimples, bells, humps, and saddle variations. Images of the 3D objects were rendered under a wide range of illuminations, material properties, and scene contexts. For each presented image, subjects performed a categorization task, in which they had to label the depicted patch by selecting one of the possible responses. Results: Subjects performed well under most conditions. However a number of degenerate cases caused confusions between categories, especially between concavities and convexities under restrictive viewing conditions. Conclusion: Our results indicate that observers are reliant on global information to estimate the curvature of local surface patches.

Acknowledgement: NSF grant BCS-0962119

43.307 Is the Perception of 3D Shape from Shading Based on Assumed Reflectance and Illumination?

James Todd[1](todd.44@osu.edu), Eric Egan[2]; [1]Department of Psychology, Ohio State University, [2]Department of Psychology, Ohio State University

This research was designed to compare three types of image shading: One generated with a Lambertian BRDF and homogeneous illumination such that image intensity was determined entirely by local surface orientation irrespective of position; one that was textured with a linear intensity gradient, such that image intensity was determined entirely by local surface position irrespective of orientation; and another that was generated with a Lambertian BRDF and inhomogeneous illumination such that image intensity was influenced by both position and orientation. A gauge figure adjustment task was used to measure observers' perceptions of local surface orientation on the depicted surfaces, and the probe points included 60 pairs of regions that both had the same orientation. The results show clearly that observers' perceptions of these three types of stimuli were remarkably similar, and that probe regions with similar apparent orientations could have large differences in image intensity. This latter finding is incompatible with any process for computing shape from shading that assumes any plausible reflectance function combined with any possible homogeneous illumination.

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43.308 Stereo-curvature aftereffects are retinal-position dependent and not scale dependent

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INTRODUCTION Stereo-curvature aftereffects involve shifts in perceived curvature after prolonged inspection of stereoscopic 3D surfaces. Domini et al. (2001) have reported that stereo-curvature aftereffects occur at the level where disparities are coded into perceived shape curvature rather than at the level where disparities are registered to disparity curvature. However, there are other possible adaptation sources in addition to shape curvature, considering stationary adaptation stimuli used in their study. Besides, little attention has been focused on position or scale dependence of the aftereffects. METHODS In our study, adaptation stimuli were dynamically presented with changing location or scale. To examine the effect of the dynamic presentation of location, different average disparity information (ADI) was generated within the visual fields subtended to test stimuli. Aftereffect magnitude was compared among three adaptation conditions (Average_Flat, Average_Convace and Average_Convex/Fixed_Size) in terms of different ADI from which the synthesized surfaces were flat, concave or convex. To examine the effect of the dynamic scale, adaptation stimuli were presented by periodical expansion-contraction in another condition (Dynamic_Size) where there was no adaptation to the shape curvature of each instantaneous presentation. Observers were required to judge whether test stimuli appeared concave or convex. The method of constant stimuli was used to determine a PSE of flat surface. The aftereffect magnitude was defined as the difference of PSE between each adaptation condition and no-adaptor condition. RESULTS ANOVA on aftereffect magnitude showed significant differences between every pair of conditions of different ADI with Average_Convex/Fixed_Size condition the largest and Average_Convace condition the smallest. But no significant difference was found between Average_Convex/Fixed_Size and Dynamic_Size conditions. CONCLUSION Stereo-curvature aftereffects are retinal position dependent and not scale dependent. The significant aftereffect in the Dynamic_Size condition suggests that the aftereffect is not only due to shape curvature but also due to other adaptation sources such as ADI.

43.309 The relative effectiveness of different line drawing algorithms at conveying 3D shape

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Line drawings depict 3D shape using "minimal" information. Computer graphics algorithms have used different geometric surface features to define lines. While no line definition is universally superior to others (Cole09), the conditions under which some line definitions outperform others, are not well understood. We examine the efficacy of two line definitions in conveying 3D shape. "Suggestive contours" are occlusions in nearby viewpoints (DeCarlo03). "Apparent ridges" are extrema of view-dependent curvature (Judd07). We expect that apparent ridges are more effective along sharper curvature extrema, while suggestive contours are more effective near more well-defined inflections. Thus, as a surface moves from a sharp sawtooth wave to a smooth sinusoidal wave, the better depiction should switch from apparent ridges to suggestive contours. Stimuli were lines drawings of surfaces with waves. They were generated by modulating the (a) radius of a cylinder, (b) height laterally on a plane or (c) height radially, using either (I) a sawtooth or (II) a sinusoidal wave. For the six resulting surfaces, one drawing using each line definition was created. We used the gauge figure methodology on Amazon's Mechanical Turk, and compared subjects' fitted settings to the ground truth of both the sawtooth and sine-wave versions. The results showed that, for sawtooth waves, apparent ridges were superior. For sinusoidal waves, the settings for the apparent ridge drawings more closely matched the sawtooth waves than the sine waves. They were thus perceived as sharper than the depicted surface. Performance of suggestive contours for sinusoidal waves varied depending on their interaction with other geometric features, such as occluding contours, parabolic lines, and ridges/valleys. The results suggest a new classification scheme for suggestive contours and apparent ridges that predicts when their usage is, or is not, effective. This can help line-drawing generation algorithms select effective lines to depict 3D shape.

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43.310 Local and global cues to depth in line drawings
Seha Kim[1,2](sehakim@rutgers.edu), Shaheera Sarwar[1,2], Manish Singh[1,2], Jacob Feldman[1,2]; [1]Department of Psychology, Rutgers University-New Brunswick, [2]Rutgers University Center for Cognitive Science

We studied the influence of local and global information on the 3D interpretation of line drawings of smooth objects. T-junctions are well known to play an important role in conveying relative depth. In previous studies (VSS2013) we found that (1) local depth ordering from T-junctions is probabilistic, with subjects' interpretation of relative depth based on inferred depth difference; and (2) estimates of depth differences propagate spatially from T-junctions along internal contours, suggesting that local and non-local cues are combined to yield a final depth interpretation. Here we examine the interaction of local and global cues in more detail by varying the aperture size through which a line drawing is visible. We created line drawings by projecting randomly-generated 3D shapes (single-axis shapes with varying curvature and cross-section). They were displayed as black contours on white background, with no other depth cues. Apertures of varying size were used to manipulate the amount and type of information available. Pairs of probe dots were placed on opposite sides of a contour, and subjects reported which dot appeared closer. We manipulated the position of the probe, the type of contour segment the probes straddled, and the aperture size. We found substantial effects of aperture size: (1) an overall increase in judgment confidence with increasing aperture size, and (2) complex interactions between the size and type of structural information available within aperture. For example, depth judgments were more reliable when the probes straddled the head of a T-junction compared to its stem and when the head was concave rather than convex. The observed effects are broadly consistent with a probabilistic model of 3D shape interpretation in which local cues to depth order, including T-junctions and contour curvature, are combined probabilistically across the shape to arrive at a final estimate of 3D structure.

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43.311 Specularity and shape from line drawings
Flip Phillips[1](flip@skidmore.edu), Julia Mazzarella[1], Pete Docter[2]; [1]Psychology & Neuroscience, Skidmore College, [2]Pixar Animation Studios

Line drawings afford observers with a surprising amount of information about shape. For example, Picasso's Fragment de corps de femme (See http://goo.gl/U9bLuh) provides an breathtakingly legible depiction of the human form that is rich with shape information from a mere four lines. Our previous work (Phillips, Casella & Gaudino 2005) as well as the work of others (Cole, Sanik & DeCarlo 2009) has investigated the nature of the underlying 3D geometric information used by artists when executing a line drawing of an object. Along with primal information like the object's boundary contour, illustrators tend to represent internal self-occlusion contours and other features largely determined by the intrinsic geometric properties of the object. It is well known that material properties that modulate the reflectance function of the object also contribute to the perception of shape. In fact, it is possible to identify objects made of glossy or shiny materials using only their specularity. This study extends our previous work on illustrators' depiction of intrinsic geometry to depiction of material properties, specifically shininess. A professional artist/illustrator depicted multiple versions of a sphere using a variety of indications of shininess. Subjects provided gauge figure adjustments for the various illustration conditions, allowing us to reconstruct the perceived shape of the depicted spheres. For all conditions, subjects underestimated the 3D curvature of the sphere. The best-fitting estimations came from stimuli with a simple highlight depiction that was roughly consistent with the curvature of the theoretical sphere. Other techniques yielded perceptual depth and curvature whose accuracy depended on the properties of the artistic indication of gloss. Geometrically consistent or plausible highlights provided more depth than those that were not.

43.312 The retinal correlate of linear perspective in slant perception
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Depicted slant is defined as slant based on linear-perspective assumptions about lines imaged on a flat surface. Slants of triangles and trapezoids were computed as a function of depicted slant and slant of the obliquely viewed picture plane. Computations were based on assumptions of parallelism and orthogonality. Perceived slant was measured during binocular viewing in a matching task. The matched slants were compared with computed slants. Matched and computed slants were highly correlated. Residual error analysis showed that both parallelism and orthogonality explained about 95% of the data. Contributions of the picture plane, signaled by binocular disparity and various monocular cues, were small for both trapezoids and triangles. The results imply that the claimed non-Euclidean nature of pictorial space is straightforwardly explained by linear-perspective assumptions. Further analysis indicated that the visual system derives slant from retinal angles alone without requiring knowledge of distance and orientation of the picture plane. Precision of the slant judgments requires a neural substrate that is able to make highly precise comparisons between orientations of lines imaged at different retinal locations. The neural basis of slant from linear perspective has not yet been clarified. Cells with long-range connections in V1, however, have features that suggest an involvement in slant perception.

43.313 Sensitivity to Spatial Frequency Chirp in the Early Visual Cortex
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Neural correlates of 3D shape from texture have been recently found in areas V3 and CIP. However the neural mechanisms that generate these neural correlates is still unknown. In previous behavioral and computational studies, we showed that 3D slant and tilt can be reliably inferred from the gradient of spatial frequency present in the texture patterns (Massot et al., 2008, 2011). In our model, such gradient can be estimated from the output of an ensemble of V1 Gabor-like filters. This leads to the hypothesis that neurons in early visual cortical areas such as V2 and V3 might combine V1 neurons' responses to develop spatial frequency gradient sensitivity. To test this hypothesis, we recorded single unit activity in V1, V2 and V3a cortical areas of non-human primates using semi-chronic multi-electrode arrays. Stimuli are static gratings displaying a spatial frequency gradient simulating a planar surface receding in depth (chirps). Slant and tilt angles are defined by the amplitude and the direction of the spatial frequency gradient. A set of 360 stimuli was created with different tilt and slant angles. Each stimulus was presented for 250ms and presented 12 times in a block design experiment onto the receptive field of the isolated neuron. Our preliminary evidence shows that V3a neurons exhibit tuning to spatial frequency gradient in addition to classical orientation and spatial frequency tuning. Neurons were tuned to either high positive gradients, high negative gradients, high absolute gradients, or did not display any preference. The recorded V1 and V2 neurons, with more localized receptive fields, were not sensitive to any gradient of spatial frequency. Overall, the obtained data suggest that the neurons in V3a have developed the building blocks for the computation of shape from texture.

43.314 Can 3D Shape be Estimated from Focus Cues Alone?
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Focus cues—blur and accommodation—have generally been regarded as very coarse, ordinal cues to depth. This assessment has been largely determined by the inability to display these cues correctly with conventional displays. For example, when a 3D shape is displayed with sharp rendering (i.e., pinhole camera), the expected blur variation is not present and accommodation does not have an appropriate effect on the retinal image. When a 3D shape with rendered blur (i.e., camera with non-pinhole aperture) is displayed, the viewer's accommodation does not have the appropriate retinal effect. We asked whether the information provided by correct blur and accommodation can be used to determine shape. We conducted a shape-discrimination experiment in which subjects indicated whether a hinge stimulus was concave or convex. The stimuli were presented monocularly in a unique volumetric display that allows us to present correct or nearly correct focus cues. The hinge was textured using a back-projection technique, so the stimuli contained no useful shape cues except blur and accommodation. We used four rendering methods that vary in the validity of focus information. Two single-plane methods mimicked a conventional display and two volumetric methods mimicked natural viewing. A pinhole camera model was used in one single-plane condition, so image sharpness was independent of depth. In the other single-plane condition, natural blur was rendered thereby creating an appropriate blur gradient. In one volumetric condition, a linear blending rule was used to assign intensity to image planes. In the other volumetric condition, an optimized blending rule was used that creates a closer approximation to real-world viewing. Subject performance was at chance in the single-plane conditions. Performance improved substantially when in the volumetric conditions, slightly better in the optimized-blending condition. This is direct evidence that 3D shape judgments can be made from the information contained in blur and accommodation alone.

Acknowledgement: NIH

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43.315 **Insights into the perception of 3-D deforming shapes and shape deformations from comparisons of foveal and peripheral performance**
Anshul Jain[1](ajain@sunyopt.edu), Qasim Zaidi[1]; [1]Graduate Center for Vision Research, SUNY College of Optometry

Optic flow patterns have been identified as the primary cues in extracting 3-D shape features (Jain & Zaidi, PNAS 2011), deformations (Jain & Zaidi, JOV 2011) and material properties (Doerschner et al., Current Biology 2011) from motion signals. These patterns can be parsed into combinations of motion divergence and shear, which in turn have been linked to 3-D shape features and deformations (Koenderink and Van Doorn, 1975), and which can selectively activate MT/MST cells. We measured human performance on identification of nonrigid shapes, classification of deformations, and detection of shear and divergence motion patterns. We compared performance on foveal versus 4 degrees peripheral stimuli with a cortical magnification factor of 2.09. In Experiment 1, observers performed an 8AFC shape identification task on point-light ellipsoidal 3-D shapes with three Gaussian features (indentations or projections), and we estimated identification thresholds as a function of indentation/projection height. Performance was similar for rigid and nonrigid shapes, but was better at fovea than at periphery. In Experiment 2, observers performed a 3AFC deformation classification task on horizontal point-light cylinders that were either rigid or flexed nonrigidly along depth or in the image plane. Observers were consistently better at identifying cylinders that flexed in the image-plane than those that flexed in depth. Surprisingly, their performance was better in the periphery than at the fovea for both nonrigidities. In Experiment 3, observers' performance was similar in the fovea and periphery for both shear and divergence patterns, indicating that the magnification factor was successful in equating sensitivity for the elementary patterns, but not for shape or deformation identification. Sensitivities to combinations of motion patterns cannot thus be predicted from sensitivities to elementary motion patterns alone. These results suggest that estimating 3-D shapes and deformations may involve heuristics that employ non-linear functions or derivatives of the elementary motion patterns.

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43.316 **Dynamic perspective cues enhance depth from motion parallax**
Athena Buckthought[1,2](athenabuck1@gmail.com), Ahmad Yoonessi[1], Curtis L. Baker[1]; [1]Department of Ophthalmology, McGill Vision Research, McGill University, Canada, [2]Department of Psychology, Carleton University, Canada

Previous studies of depth from motion parallax have employed orthographic rendering of moving random dot textures. Here we examine the effects of more naturalistic motion parallax stimuli using textures with a 1/f spectrum and dynamic perspective rendering. We compared depth perception for orthographic and perspective rendering, using two types of textures: random dot patterns and 1/f Gabor micropatterns. Relative texture motion (shearing) was synchronized to the observer's horizontal head movements and modulated with a low spatial frequency (0.1 cpd), horizontal square wave envelope pattern. The stimulus was presented in a circular window of 36 degrees diameter, at 57 cm viewing distance. Four observers performed a two-alternative forced choice depth-ordering task, in which they reported which modulation half-cycle of the texture appeared in front of the other. In addition, noise thresholds were obtained for depth ordering at a criterion level using a coherence noise task. Furthermore, we examined the effects of removing each of the three types of cues that distinguish dynamic perspective from orthographic rendering: (1) small vertical displacements, (2) lateral gradients of speed across the extent of the square wave modulations, and (3) speed differences in rendered near versus far surfaces. For both textures, depth perception was better with perspective rendering than with orthographic projection. Depth perception systematically declined, with greater differences between the two types of rendering, as rendered depth increased. Similar results were found for naturalistic 1/f textures, but performance was somewhat less than with random dots. Removal of any of the three cues impaired performance, though to different degrees in different individual subjects. In conclusion, depth ordering performance is enhanced by all of the dynamic perspective cues, but is diminished with 1/f textures.

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43.317 **The effect of age upon the perception of 3-D shape from motion**
Jacob Cheeseman[1](jacob.cheeseman910@topper.wku.edu), J. Farley Norman[1], Jessica Pyles[1], Michael Baxter[1], Kelsey Thomason[1], Autum Calloway[1]; [1]Department of Psychological Sciences, Ogden College of Science and Engineering, Western Kentucky University

In previous research, we evaluated the ability of older, middle-aged, and younger adults to discriminate the 3-dimensional (3-D) shape of curved surfaces defined by optical motion. Temporal correspondence was disrupted by limiting the lifetimes of the moving surface points. It was found that in order to discriminate 3-D surface shape reliably, the younger and middle-aged adults needed a surface point lifetime of approximately 4 views (in the apparent motion sequences). In contrast, older adults needed a much longer surface point lifetime of approximately 9 views in order to reliably perform the same task. In the current experiment, the negative effect of age upon 3-D shape discrimination from motion was replicated. In this experiment, however, 20 younger and older participants' abilities to discriminate grating orientation and speed were also assessed. Edden et al. (2009) have recently demonstrated that behavioral grating orientation discrimination correlates with GABA (gamma aminobutyric acid) concentration in human visual cortex. Our current results demonstrate that the negative effect of age upon 3-D shape perception from motion is not caused by impairments in the ability to perceive motion per se, but does correlate significantly with grating orientation discrimination. This finding suggests that the age-related decline in 3-D shape discrimination from motion is related to decline in GABA concentration in visual cortex.

43.318 **Effects of reflectance and object motion in estimating 3D structure**
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Our interaction with the physical world requires the visual system to estimate and represent the 3D geometry of objects from various visual cues. Image motion is a particularly powerful cue to 3D structure, as has been investigated in many experiments using classical shape from motion (SFM) stimuli. However, these studies commonly assume - implicitly or explicitly - a diffusely reflecting surface. While optic flow in these cases is directly linked to the object motion; its behavior when the surface is specular, the specular flow, is related to the 3D curvature of the underlying shape (Koenderink & van Doorn, 1980). While this specular flow may facilitate a complete reconstruction of the 3D shape in the theoretical sense (Adato et al. 2010, 2011), its different nature may also bias the perceptual estimation of 3D shape from motion. Indeed, in previous work we have shown that specular flow systematically biases the perceived objects' rotation axis (Dörschner et al 2013), an implicit computational step in SFM. Here we investigate whether the perceived 3D shape of moving specular objects differs systematically from that of matte-textured ones. Stimuli were bumpy, 3D wavers rendered either with a diffusely reflecting texture map or as a specular surface. During presentation these objects rotated back and forth through 20 degrees, or they were kept static as a control condition. This design resulted in 2 (motion, static) x 2 (matte, specular) trial types where observers (N=7) were asked to judge local shape and curvature at indicated locations by adjusting a rotation-invariant shape index probe. Results indicate that shape estimates differ between static and moving conditions, across different reflectance properties, and across locations on the object. We account for these results with a computational approach to specular shape from motion.

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43.319 **Depth perception from motion parallax: dependence on texture spatial frequency and orientation**
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Previous studies of motion parallax have employed random dot textures, which are broadband in terms of spatial frequency and orientation. However most neurons in the early visual system have specific tuning for spatial frequency and orientation. Furthermore, neurons selective for texture boundaries exhibit distinct tuning for high spatial frequency textures. Here we examine the effect of texture spatial frequency and orientation on depth perception from shear motion parallax. Visual stimuli consisted of textures created from randomly distributed Gabor micropatterns whose

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relative shearing motion was synchronized to the observer's horizontal head movements and modulated with a low spatial frequency (0.1 cpd), horizontal square wave envelope pattern. We measured psychophysical performance in a 2AFC depth-ordering task, for Gabor elements of varying spatial frequency (1 to 8 cpd) and orientation (vertical or horizontal). All of the Gabor micropatterns in each texture were of the same spatial frequency and orientation. Performance was measured for varying levels of added coherence noise, to obtain coherence noise thresholds. Furthermore, we varied the density and the contrast of Gabor micropatterns to measure the possible importance of sparseness and element contrast. At low spatial frequencies, performance was better for vertical than for horizontal Gabors while at high spatial frequencies (e.g. 8 cpd) there was no effect of orientation. However at mid-range spatial frequencies (e.g. 4 cpd), surprisingly, depth for most observers was better for horizontal than for vertical Gabors. Density of the micropatterns had little impact on psychophysical performance. Decrease in contrast increased the difference between performance for vertical and horizontal Gabor micropatterns. These results demonstrate that the mechanism for depth from motion parallax is highly dependent on the nature of the constituent surface textures.

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43.320 **Depth cue integration with the Intrinsic Constraint Model and the Motion/Pursuit Ratio for motion parallax.** Mark Nawrot[1](mark.nawrot@ndsu.edu), Jessica Holmin[1], Keith Stroyan[2], Fulvio Domini[3]; [1]Center for Visual and Cognitive Neuroscience, Department of Psychology, North Dakota State University, [2]Math Department, University of Iowa, [3]Department of Cognitive, Linguistic & Psychological Sciences, Brown University

To generate a singular impression of depth, the visual system combines independent depth cues in a scene. However, these signals vary greatly in how accurately the underlying geometry is represented. Our goal was to determine how the Intrinsic Constraint (IC) Model of depth cue integration accounts for perceived depth magnitude in a motion parallax (MP) and binocular disparity (BD) cue combination study. We previously determined perceived depth magnitudes when MP and BD cues are combined. To test the IC model, standard deviations (σMP and σBD) for depth magnitude discriminations in singular cue conditions must be determined in order to independently estimate the signal-to-noise ratios for each individual cue. Observers viewed random-dot stimuli through a mirror stereoscope providing ocular separation for stereo stimuli, monocular viewing of the parallax stimuli, and stable convergence and accommodation. To determine σMP for perceived depth magnitude of a translating MP stimulus, MP stimuli were compared to other MP stimuli in a 2IFC, "greater depth magnitude" procedure. MP stimuli were quantified with the Pursuit/Motion Ratio whereby MP stimuli translated laterally generating pursuit (1.1 - 3.3 d/s) while dots within the stimulus window translated laterally (peak 0.09 - 0.55 d/s). To determine σBD of the perceived depth magnitude of a stationary BD stimulus, BD stimuli were compared to other BD stimuli. BD stimuli had a range of disparities (1.5 - 15 min). For each MP and BD stimulus, psychometric function parameters, including slope (β), were estimated using a cumulative normal function. The σs were calculated from β, noting that the empirical depth estimate was affected by the error in both the test and comparison stimuli. Using these σs, the IC model produced cue combination predictions that were similar to the depth magnitudes measured in the empirical cue combination paradigm, which cannot be accounted for the MWF theory of cue integration.

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Eye movements: Saccade mechanisms and metrics

Monday, May 19, 8:30 am - 12:30 pm
Poster Session, Jacaranda Hall

43.321 **Contextual saccade adaptation can induce contextual perceptual effects** Reza Azadi[1,2](r.azadi9@gmail.com), Mark Harwood[2]; [1]The Graduate Center, City University of New York, [2]Department of Biology,City College of New York

Introduction: Saccade adaptation not only influences saccade amplitude, but can also alter visual perception: it can induce mislocalization of flashed visual targets, presented immediately before saccade execution. Saccade adaptation is also contextual: different gains can be maintained for the same vector depending on visuomotor context. Can perceptual mislocalizations also be context-dependent? Methods: Context was defined by circular motion direction (clockwise vs. anti-clockwise). While maintaining fixation, subjects viewed a circularly moving target. There were 4 trial types. 1- Localization-only: subjects stayed on a fixation point throughout the trial, which ended after they used a mouse cursor to localize a bar that had flashed briefly near the target. 2- Saccade-only: a go-signal (fixation point offset) elicited saccades towards the moving target. 3- Target-On: after a go-signal, but before the subsequent saccade, bars were flashed near the target, which continued moving and were visible for a short time post-saccade. After the target disappeared, subjects localized the flashed bar with the mouse cursor. 4- Target-Off: as in Target-On, but the target disappeared upon saccade onset. Contexts were interleaved throughout separate baseline and adapt sessions; the first half of each session were saccade-only trials, followed by all 4 trial types randomly interleaved. During adapt sessions, the target stepped inward or outward depending on motion direction. Results: Mislocalization in Target-on, Target-off and Localization-only tasks were significantly different for the two contexts, and these mislocalizations were proportional to the size of contextual saccade adaptation. Moreover, the mislocalization within each Target-off trial was significantly correlated with saccade amplitude, but not during the Target-on trials. Discussion: We can induce context-dependent changes in visual perception by a simple motor adaptation task, and the size of this perceptual effect depends on the size of the saccade adaptation. Remarkably, the perceptual effects transfer to non-saccade, Localization-only trials.

43.322 **Saccadic plasticity induced by a periodic disturbance of visual feedback** Carlos Cassanello[1,2](carlos.cassanello@bccn-berlin.de), Sven Ohl[1,2], Martin Rolfs[1,2]; [1]Bernstein Center for Computational Neuroscience Berlin, Germany, [2]Department of Psychology, Humboldt University Berlin, Germany

Goal. Saccadic adaptation restores the correct targeting of visual objects when saccades miss their goals systematically. Here, we assessed global changes in the gain of saccade amplitudes (Rolfs et al., Vision Res., 2010) for continuously varying post-saccadic visual feedback using a Bayesian approach for parameter estimation. Methods and Results. Observers made saccades following a sequence of 304 target steps with amplitudes drawn randomly from a uniform distribution between 4 and 12 degrees with unconstrained saccade directions. During each saccade, an intra-saccadic shift (ISS)—following a continuous sinusoidal variation as a function of the trial number—shifted the target along its vector by -25% (inward) to 25% (outward) of the presaccadic target eccentricity. We modified a method developed for the study of adaptation in manual reach movements (Hudson & Landy, 2012) to model changes in saccadic gain as proportional to the target ISS with four parameters: an overall frequency, a saccade amplitude gain, a time lag, and a global shift to account for intrinsic hypometria of the saccades. We constructed a probability distribution over model parameters after integrating over an internal variable that characterizes the width of the landing error distribution. Subsequently, we obtained a posterior marginal for each parameter by integrating over the remaining three. Using this method, we were able to extract the slow time-scale of the overall ISS variation with a delay of 15 to 30 trials, in spite of the high variability in the saccade landing error and a low overall degree of adaptation. Conclusion. Global saccadic gain adaptation tracks a continuously varying ISS with a similar frequency of variation and a temporal lag of a few trials. Evidence of this fast plasticity can be detected and extracted from a short experimental session in spite of the high variability in the saccade landing error.

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43.323 **Rotation of the perceived vertical axis induced by saccadic adaptation** Barbara Dillenburger[1](barbara.dillenburger@gmail.com), Michael Morgan[1]; [1]Max Planck Institute for Neurological Research, Cologne

Introduction. Global saccadic adaptation to a translational shift has been demonstrated previously. We ask here: first, can saccadic adaptation be induced with a comparatively sparse stimulus and an angular shift, and second, does global adaptation of saccades affect the perception of the adapted space? We designed a circular stimulus paradigm to assess saccades to and perception of shifted target locations. Methods. Stimuli were presented on a CRT (Sony GDM-F500, 80Hz, 1440x1050) using Psychtoolbox & Matlab. Eye movements were recorded using Eyelink2000 at 1000Hz. Three subjects fixated a central fixation spot. Saccade targets were randomly presented on one of 6 evenly spaced locations on the circumference of a notional circle with 8.8deg radius. At saccade onset, the target was shifted clockwise (step condition, 5deg polar angle) or maintained (no step condition). After 1sec, a saccade target close by central fixation was presented and also shifted (in step conditions) during saccading, thereby moving it to the central fixation spot. Adaptation transfer test targets (turned off during saccading, step after landing) were presented at intermediate, untrained locations on the circles' circumference. Interleaved with eye movement

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trials, the perceived vertical was measured in a temporal 2AFC paradigm (was the first or second target closer to the vertical axis?). Subjects had to maintain central fixation throughout the perception trial. Results. Average saccadic endpoints were found shifted from 'no step' to 'step' conditions across sessions, showing that our paradigm effectively induces saccadic adaptation. Shifts were consistent across stimulus locations, and also transferred to untrained test locations. Perceptually, subjects' individual vertical axes were rotated clockwise in the 'step' condition as compared to the baseline 'no step' condition. Conclusion. Even sparse, yet consistent saccadic adaptation to an angular shift can transfer to untrained locations, and result in rotation of the perceptual space as measured by the perceived vertical.

43.324 **Spatial scale strongly modulates saccade adaptation.** Mark Harwood[1](mharwood@sci.ccny.cuny.edu), Afsheen Khan[1], Annabelle Blangero[1]; [1]Department of Biology, City College of New York, CUNY

Introduction: Saccade experiments have predominantly used small, precise targets, despite our everyday viewing consisting of saccades between much more spatially extended objects. Recently spatial scale has been found to strongly affect saccade decisions ('Size-Latency Effect'), with larger targets invoking weaker decision signals, but little is still known about possible effects of scale on saccade adaptation. We hypothesized that the spatial spread of larger targets may increase uncertainty in error signals from large targets, leading to reduced adaptation. Methods: In three experiments we tested the effect of target size on the adaptive efficacy of intra-saccadic target steps. Experiment 1 used different diameter rings. In Experiments 2 and 3, subjects were required to bisect equal-length line pairs, at different separations. Experiment 3 varied the size of the intra-saccadic step from trial-to-trial in a sine wave pattern. Results: Contrary to our initial hypothesis, we found that larger targets (or larger target separations) produced significantly, and proportionally, larger adaptation. Larger targets were shown to have longer corrective saccade latencies due to the Size-Latency Effect. We found a positive relationship between corrective saccade latency and magnitude of adaptation. Discussion: Larger targets cause larger saccade adaptation. We argue that the increased time to make corrective saccades in these larger targets gives a greater urgency to adapt errors via the primary saccade. This suggests a new, more complex error signal for saccade adaptation, and underlines the importance of examining spatial scale during active vision processes.

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43.325 **Dichoptic saccadic adaptation** Guido Maiello[1,2](guido_maiello@meei.harvard.edu), William J. Harrison[1], Peter J. Bex[1]; [1]Schepens Eye Research Institute, Department of Ophthalmology, Harvard Medical School, [2]UCL Institute of Ophthalmology, University College London

In order to maintain accurate control of eye movements, the oculomotor system rapidly adapts to visual error based on foveal feedback. The short term plasticity of the saccadic system can be tested using intrasaccadic target displacements which induce visual motor error. The saccadic system rapidly adjusts to the perceived error by modifying the amplitude of saccadic eye movements. We tested in four participants whether it is possible to induce disconjugate saccadic adaptation by presenting intrasaccadic displacement to only one eye. We presented stimuli dichoptically using a stereo shutter-glass system. At the beginning of each trial, subjects fixated a central binocular fixation target. After a delay, the target was displaced by 10 degrees. During the preadaptation and postadaptation phases, the target was presented in the same location to both eyes without intrasaccadic displacement. In the adaptation phase, the target for the eye moving in the temporal direction was displaced one degree outward during the saccade. This induced uncrossed disparity which required divergent eye movements and induced a stereoscopic percept. We found that, in the preadaptation phase, the eye moving in the nasal direction systematically undershot the target by a greater distance than the eye moving in the temporal direction. These errors required subsequent vergence movements to correctly fixate the target. In the adaptation phase, the saccade amplitude changed for both eyes. However, the eye in which the intrasaccadic target displacement occurred had a greater change in amplitude, and this was the case for both leftward and rightward eye movements. During the postadaptation phase, saccade amplitudes returned to baseline within just a few trials, but the data suggest that the adapted eye takes longer to return to baseline. Therefore, we found evidence of both conjugate and disconjugate changes in saccadic adaptation, which supports the possibility of dissociable spatial maps for each eye.

43.326 **Dynamics of target and distractor spatial averaging in the global effect** Woo Young Choi[1,2], Jayalakshmi Viswanathan[2], Manfred Kvissberg[2,3], Jason Barton[2]; [1]Department of Medicine (Neurology), University of Alberta, Canada, [2]Department of Medicine (Neurology), Department of Ophthalmology and Visual Sciences, University of British Columbia, Canada, [3]Faculty of Medicine, Linköping University, Sweden

Background: In the global effect, saccades are displaced towards a distractor that is near in location to the target, an effect that is thought to reflect neural averaging in the superior colliculus. The temporal profile of this averaging process has not yet been investigated, however. Objective: We studied how the global effect varied with the degree of temporal dissociation between target and distractor appearance. Methods: In the first study, the target was flashed for 10ms at 8° horizontal eccentricity, followed after an interval varying between 0ms and 100ms, by a 10ms distractor at either 4° or 12° horizontal eccentricity. In the second study, the distractor appeared first, either as a 100ms flash or with sustained presence, at the same locations, and followed after an interval varying between 0ms to 800ms by the target. We analyzed saccade amplitude data from 12 subjects in terms of offsets, latencies and integration time. Results: In the first experiment, the offset between the target and distractor did not influence the global effect. The global effect occurred only in saccades with latencies between 140 and 300ms, or with integration times between 80 and 360ms. In the second experiment, the global effect decreased significantly with 100ms of offset between the distractor and target, but was still evident. The global effect was stronger when the distractor was continuously present throughout the trial. Similar to the first experiment, we found the global effect only in saccades with latencies between 80 and 350ms. Conclusion: The global effect can occur despite separation of the target and distractor in time, suggesting that there is substantial persistence of distractor-related activity that is available for spatial averaging in the superior colliculus.

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43.327 **Saccadic reaction time distributions follow the matching law in a concurrent variable interval reinforcement schedule** Laurent Madelain[1,2](laurent.madelain@univ-lille3.fr); [1]Psychology dept., Univ Lille Nord de France , [2]Institut de Neurosciences de la Timone UMR 7289 CNRS & Aix-Marseille Univ

Studies of decision-making process revealed that animals are sensitive to the sources and timing of rewards and use these variables to choose among alternatives. In particular experiments on foraging behavior indicate that the distribution of time among foraging sites is proportional to their relative value. These relations were expanded to a general principle of choice termed the matching law (Herrnstein, 1961) which states that the fraction of choices made to an option will match the fraction of total income earned from that option. Because saccadic reaction time distributions are known to be strongly affected by reinforcement schedules (Madelain et al, 2007) we now ask whether saccade latencies as well could match reinforcement proportions in concurrent schedule. Our procedure was similar to the one used by Sugrue et al (2004) except that reinforcement depended on saccade latencies rather than on target choice. We had one subject (the author) make saccades to a visual target stepping horizontally by 10 deg at a 0.6Hz rate. Fast and slow latencies (defined with respect to the first and last quartile of baseline RT distribution, [100-160]ms and [217-320]ms respectively) were reinforced in a concurrent Variable Interval schedule with unsignaled changes of reinforcement ratios (9/1, 1/1 or 1/9) during extensive training. Using the generalized matching equation we found that saccade latencies were well controlled by the current schedule (sensitivity=0.704, bias=-0.004). A moving 30-trials temporal window revealed that local distributions of latencies were correlated with the local ratios of obtained reward ($R2=0.79$, $P<0.05$). Interestingly, saccade peak velocities were significantly higher in the "fast" than in the "slow" latencies. These data indicate that saccade latency distributions follow the rules of other choice behavior and may depend on past behavior more than previously thought.

43.328 **Lateral interactions of competing stimuli modulate visual response fields in the frontal eye fields** Robert Marino[1](marinor@queensu.ca), Amirsaman Sajad[1], Hongying Wang[1], Xiaogang Yan[1], Douglas Crawford[1]; [1]Center for Vision Research, York University, Ontario, Canada.

Natural vision involves processing complex visual information where multiple objects or features interact to influence current gaze position. Such interactions can be competitive (e.g. multiple salient items competing for foveation) or complimentary (e.g. using allocentric cues to help guide gaze shifts). Experimentally however; the influence of stimulus interactions are often ignored when the spatial response fields (RF) of visual neurons are

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mapped with single stimuli. Historically, it has been assumed that RFs are stable across altered task demands or stimuli complexity. This classical idea of stable RFs has been challenged recently by Cavanaugh et. al (JNeurosci, 2012) who showed that visual RFs in the frontal eye fields (FEF) were influenced by stimulus size. We hypothesized that lateral interactions (local excitation, distal inhibition) resulting from multiple stimuli should be apparent within individual FEF RFs since they represent computationally important elements of visuomotor transformations. To address this issue we recorded from visually responsive FEF neurons in head-free monkeys while they performed variants of a rapid visual RF mapping task. Complete visual RFs were mapped with 1 (control) or 2 simultaneously presented stimulus flashes. When a 2nd stimulus was presented, it could appear inside or outside of the classical RF. On some trials, a saccade target was presented (either inside or outside the RF) that remained visible during the RF mapping flashes and was saccaded to at the end of the trial. Results show that the addition of a 2nd stimulus or saccade target increased RF size and visual response magnitude when it was presented within the RF, whereas a 2nd stimulus presented outside the RF reduced RF size and visual response magnitude. These results provide insight into the nature of excitatory and inhibitory interactions between multiple visual stimuli in the FEF. Supported by CIHR, NSERC CREATE, and CRC.

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43.329 Dissecting the delay in the saccadic size-latency phenomenon.

Jelmer De Vries[1](vriesdejelmer@gmail.com), Mark Harwood[1]; [1]City College of New York

Saccade latencies are often found to rise for targets near the fovea. While such findings are typically assumed to be contingent on the saccade amplitude, recent evidence shows that the size of the saccade target also plays an important role (Harwood et al., 2008). That is, latencies for proximal targets increase drastically as a function of the target's size. Here we investigate what underlies this interesting size-latency phenomenon. As the increase in latency stems from the manipulation of a visual property, one potential explanation for this phenomenon is that the decision of where to saccade to next is based on a longer period of accumulating visual input (the visual integration window). Using a luminance selection task in which target-distractor difference varied throughout the trial (Experiment 1) we compared the visual integration window for both smaller and larger targets. Despite considerably longer latencies for larger targets (exceeding 70ms longer for some observers), visual integration windows were similar across target sizes. Therefore, next we asked whether the final stages of saccade preparation take longer. In Experiment 2 we focused on the so-called saccade dead time, the period of the latency during which new input no longer affects the saccade destination. Using a double-step task, we evaluated the observer's ability to update the initial saccade destination when the target steps shortly before saccade execution. Similar dead times were found for both small and large targets. In summary, the phenomenon can best be viewed as increasing the period between the visual integration window and the final stages of saccade preparation. The lengthy delay between the integration of visual input and saccade initiation has been an enduring conundrum. As the current results demonstrate that this delay can be modulated using the size-latency phenomenon, understanding this phenomenon can provide crucial insights into the sensorimotor decision process.

43.330 Investigating the time course of luminance and orientation influences on saccadic behavior

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Visual features such as luminance and orientation are known to influence oculomotor behavior. However, as suggested in models of saccade generation, they may intervene with different time courses, through respectively direct (retinal) vs. indirect (retino-cortical -V1) projections to the Superior Colliculus. To test this hypothesis, we compared the time required to initiate a saccade toward a peripheral visual target that was defined either by its average luminance or its orientation relative to a textured background. In a first experiment, we used a forced-choice saccade task (Kirchner & Thorpe, 2006), in which the target appeared randomly to the left or to the right of an initial fixation cross, and at a variable eccentricity. The target was a vertical array of Gabor patches whose luminance and orientation relative to the background (a grid of 25°-tilted Gabor patches) were varied randomly (method of constant stimuli). This allowed us to estimate for each participant, the luminance/orientation thresholds that yielded a saccade in the correct direction in 98% of the cases, and hence determine the levels that made luminance and orientation targets equally salient. In the second experiment, we then measured saccadic reaction times (SRT) for these salience-matched, luminance and orientation targets. We observed that SRT were longer for orientation- compared to luminance-defined targets. Irrespective of target eccentricity, individual SRT distributions were shifted by about 20 ms on average, towards longer latencies for orientation- compared to luminance-defined targets, while saccade accuracy remained unaffected. Thus, orientation intervenes later than luminance in determining when the eyes move, probably as a result of the different neural substrates involved in the extraction of these two visual features, and the slightly longer route to the SC for orientation compared to luminance. Implications for models of eye guidance in natural scenes, where luminance and orientation presumably contribute equally will be discussed.

43.331 Saccade Endpoint Variability During Efficient and Inefficient Visual Search

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We investigated the coordination of saccade target selection and saccade production by measuring saccade endpoint variability with and without visual distractors. Four macaque monkeys performed both efficient popout (red/green) and inefficient form (T/L) visual search task over 299 sessions. Each trial consisted of 2, 4, or 8 iso-eccentric items, one of which was the target. We compared the distributions of variability in polar angle and amplitude of endpoints of saccades directed to the target with and without distractors. We found that visual search distractors influence saccade production. Irrespective of search efficiency, monkeys demonstrated increasing variability of endpoints in polar angle with increasing search set size. We interpret this finding in relation to the pattern of presaccadic activation in superior colliculus and frontal eye field motor maps. The center of gravity of the pattern of activation in the motor map dictates saccade endpoints (van Optal & van Gisbergen, 1989 Vision Res. Vol 29:1183). Greater variation in endpoints entails greater variation in this center of gravity, implying that neural saccade target selection does not entirely filter out distractors. The magnitude of systematic and random scatter of saccade endpoints during visual search is important to characterize because ideal observer models of visual search behavior assume that saccade endpoints are an accurate readout of visual processing (e.g. Beutter et al. 2003 J Opt Soc Am A Opt Image Sci Vis. 20:1341; Najemnik & Geisler 2005 Nature. 434:387).

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43.332 Saccadic system rhythmicity accounts for inhibition of return

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The birth of modern-day cognitive neuroscience came about through the discovery of a curious phenomenon. If a cue is presented at a location, the efficacy of subsequent orienting to that location is improved relative to other locations only immediately afterwards. A few hundred milliseconds later, orienting is associated with much larger costs. These costs have been termed "inhibition of return" (IOR), alluding to cognitive strategies avoiding perseverance at one location. However, despite this hypothesis, the origins of IOR remain elusive. Here we show that classic IOR may simply reflect saccadic system rhythmicity and how it is reset by stimulus onsets. We hypothesize that cue onset always creates an orienting reflex, but it is manifested in microsaccades. This orienting reflex represents a phase resetting of the saccadic system (Hafed & Ignashchenkova, J. Neurosci., 2013). If a subsequent target is now presented, the efficacy of orienting towards it will depend on the phase of saccadic rhythms at which the target appears: if the oculomotor system is already prepared to move in a direction, reaction times opposite this direction will be slower. To test this, we ran 16 humans in a cueing paradigm. Subjects fixated a central spot, and a brief cue (35-ms, 1-deg radius white circle) appeared 5 deg to the right/left. After a cue-target-onset-asynchrony (47, 94, 141, 247, 541, or 1247 ms), a second circle appeared at the cued/opposite location. Saccadic reaction times (SRT) replicated classic IOR. Microsaccades showed systematic rhythmicity, which was reset by cue/target onset. SRT distributions critically depended on the phase of this rhythmicity, and IOR was strongest when targets appeared at a time of increased microsaccades opposite the cue. Thus, when the whole gamut of saccadic activity is considered, IOR becomes an emergent property of phase modulations of saccade/microsaccade rhythms, largely independent of high-level cognitive strategies.

Acknowledgement: CIN/DFG, Germany

43.333 **How the distorted representation of visual space in our brain constrains the way we move our eyes.** Françoise Vitu[1](Francoise.Vitu-Thibault@univ-amu.fr), Soazig Casteau[1], Delphine Massendari[1], Lotje van der Linden[1]; [1]Laboratoire de Psychologie Cognitive, CNRS, Aix-Marseille Université

The representation of visual space is distorted in several areas of the brain, including the Superior Colliculus (SC) where population averaging presumably determines the amplitude of saccadic eye movements. We previously showed, based on human behavioral data that this is responsible for the rather systematic tendency to undershoot the center of eccentric, simple-shape stimuli (Vitu & Casteau, VSS 2013). Here, we reveal that population averaging in the distorted map of the SC is a general principle that accounts for the metrics of saccades towards stimuli of varying sizes and shapes, irrespective of the task and the cognitive content of the stimuli, and wherever stimuli appear in the visual field. Our demonstration relies on a very simple approach that consists of (1) recording the eye movements of human participants while they execute a range of tasks (from aiming at the center of a single peripheral visual target to reading series of words), and (2) plotting the distributions of the eyes' initial landing sites in both visual and collicular spaces, using for the latter, Ottes et al.'s (1986) logarithmic mapping function of the SC in monkeys. We observe that as stimuli are presented more peripherally, landing sites, when expressed in degrees of visual angle, become more variable and are more greatly biased towards the fovea. However, landing sites, when expressed in millimeters of collicular space are normally distributed around the center of the stimulus image, and with comparable variability. Thus, where the eyes move is strongly constrained by the tendency for neural activity in the distorted map of the SC, to build up at the center of the stimulus pattern. The neural bases of saccade programming and implications for models of eye guidance in complex cognitive tasks will be discussed.

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43.334 **Alpha-Stable Distributions and Saccadic Foraging** William Hahn[1](hahn@ccs.fau.edu), Elan Barenholtz[1]; [1]Center for Complex Systems and Brain Sciences, Florida Atlantic University

Given the limited perceptive range and informational capacity of the visual system, what is an optimal eye-movement strategy? While previous research has considered which image locations are informationally rich, much less research has considered general factors of saccadic movements, such as how often and how far the eyes should move under an optimal information-gathering strategy. With a higher resolution in the fovea and limited processing resources, the visual system must decide when an image region has undergone sufficient processing to move to a new location. Gaze shifts can thus be thought of as the visual system foraging for areas rich in visual saliency. Here we use statistical models to explore the overlap between simple animal foraging and gaze relocation. Research gathering behaviors of other species show that foragers try to minimize the distance travelled between targets to maximize their energy gain. An optimal foraging strategy must balance intensification with diversification, searching around the current solutions while making sure to explore the space efficiently. Heavy-tailed (alpha-stable) distributions have been shown to be advantageous when searching for randomly and sparsely distributed resources, yet research remains limited because closed form analytic expressions for these non-Gaussian distributions are not available. In the current study, we employ recently developed numerical methods to fit alpha-stable parameters to saccadic distributions. We find that the measured alpha values are predictive of scene geometry and distractor distribution, with measured alpha parameters falling in between Gaussian and Levy and decreasing as search difficulty increases. This suggests that eye movement distributions do not have closed form solutions and should be characterized by numerical approximations of stable distributions. Furthermore, these results demonstrate the potential utility of a new set of analytic tools for exploring this potentially rich source of behavioral data.

43.335 **Saccadic timing is determined by both accumulated evidence and the passage of time** John Wilder[1,2](jdwilder@yorku.ca), Cordelia Aitkin[2]; [1]Centre for Vision Research, York University, [2]Department of Psychology, Rutgers University

One important saccadic decision is how long to fixate a given location. Two views of saccadic timing have been proposed. In Evidence models, the eye remains fixated until necessary visual information is acquired. In Timer models, the duration of a fixation is governed by an internal clock. To distinguish these models, subjects viewed sequentially accumulating dots (1 dot/53 ms) sampled from a Gaussian distribution and decided whether the dots came from a mean to the left or right of a reference line. Level of difficulty was determined by the distance of the mean to the reference line. Blocks of trials were either easy, difficult, or a mix. RTs in the mixed condition fell between RTs for the blocked conditions (context effects). The value of the accumulated evidence on each trial (computed based on the locations of the presented dots) increased with RT. A timer model failed to predict the RT distributions in the mixed condition, and the observed relationship between RT and evidence. An evidence model (with noisy criteria and an optimal decision rule), captured the context effect, but did not predict the observed relationship between RT and accumulated evidence. A hybrid model used a weighted average of two independent probabilistic stopping signals, time and evidence. Both signals increased stopping probability sigmoidally. The weight parameter reflects the level of influence of evidence and time. Weights varied across subjects for easy blocks; however, all subjects gave higher weight to evidence in difficult blocks. The model captured the RT distribution, effects of context and relationship between evidence and RT. The success of the hybrid model shows the flexibility of strategies of saccadic timing, allowing emphasis on either evidence or elapsed time in attempts to produce the most efficient saccadic scanning patterns.

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43.336 **Correcting video-based eye tracking signals for pupil size artifacts** Kyoung whan Choe[1](kywch@snu.ac.kr), Randolph Blake[1,2], Sang-Hun Lee[1]; [1]Department of Brain and Cognitive Sciences, Seoul National University, [2]Vanderbilt Vision Research Center and Department of Psychology, Vanderbilt University, Nashville, TN 37240, USA

Some video-based eye tracking techniques rely on estimating pupil center to measure eye movements. However, estimation of pupil center can be distorted by variations in pupil size, which are known to reflect changes in retinal illuminance, arousal and task demands. Earlier studies have shown that these distortions can create spurious changes in the measurement up to several degrees in visual angle, thus weakening the validity of results reliant on accurate estimates of eye position. We have developed and validated a regression-based method for correcting this pupil size artifact. In a visually guided saccade task, twenty-three observers either maintained fixation on a dot (diameter 0.12°) located in the center of a monitor screen (fixation condition) or tracked the small dot as it jumped 0.12° leftward or rightward from the center at pseudorandom times (saccade condition). Eye positions and pupil size were sampled binocularly at 500 Hz using a video-based eye tracker (EyeLink 1000, SR Research). The task allowed us to distinguish actual eye movements, including microsaccades, from spurious eye movement signals associated with pupil size changes. Confirming previous reports, we found high correlations between measured gaze positions and pupil size, which accounted for 43.6% ± 29.5% (mean ± SD) and 21.3% ± 25.8% of the variance in the left and right horizontal eye traces, respectively, and 35.6% ± 27.6% and 35.0% ± 27.7% of the variance in the left and right vertical eye traces, respectively. Notably, the pupil-confounded mean gaze positions of the central dot in the fixation condition deviated substantially from those of the other fixation targets in the saccade condition (absolute deviation=0.22°±0.14°), but after correction the deviation was reduced significantly (0.12°±0.09°; paired t-test p=0.001). Our findings confirm that the inherent imprecision of pupil-based eye tracking can be effectively mitigated thereby providing more accurate, reliable eye movement measurements.

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43.337 **Clarifying the validity of eye movement measures from various eye tracker types; a systematic study of data quality, event detection algorithms and filters.** Fiona Mulvey[1](Fiona.Mulvey@humlab.lu.se), Raimondas Zemblys[2], Linnea Larsson[3], Kenneth Holmqvist[4]; [1]Dept. Psychology & Humanities Lab, Lund University, [2]Humanities Lab, Lund University, [3]Electrical and Information Technology, Lund University, [4]Dept. Psychology & Humanities Lab, Lund University

The validity of eye-movement-based research rests on the assumption that the algorithms applied to variously sampled signal correctly characterise small changes in eye behaviour. Despite this fundamental assumption, a systematic comparison of algorithms and filters across typical data quality, as measured from various commercial systems, is lacking. Comparing systems and algorithms for accuracy of event characteristics was previously approached through a) dual-recording of the same eye with two systems, e.g. VOG and coil, which is limited due to the different nature of each signal type b) recording with 2xVOG systems concurrently, which presents problems with system IR illumination profiles, c) recording each system separately in a controlled test environment with a robotic artificial

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eye working comparably on all systems, reaching the velocity of real eye movements, or d) events based on expert hand-coding of recorded data as 'gold standard' – requiring that experts agree. This study takes the novel approach of recording optimal data on a DPI eyetracker during fixation, saccade and smooth pursuit of varied amplitude and velocity, recording the same participants on several VOG systems to model spatial and temporal noise, and applying the error measured from each participant to comparative DPI datasets. We compare the resulting datasets to the original DPI data for fixation number, fixation duration, saccade amplitude, velocity, acceleration and peak velocity characteristics following the application of several current filter and event detection algorithms. The results provide a guide to improved eye movement measures from a particular study, and improved system performance, based on objective analysis. Results are discussed in terms of their relevance for anyone doing research with eye trackers, as well as for those developing systems and analysis methods. It contributes towards a larger study with the aim to bring clarity regarding which measures are valid from various types of eye trackers.

Eye movements: Natural tasks and environments

Monday, May 19, 8:30 am - 12:30 pm
Poster Session, Jacaranda Hall

43.338 Saccade direction and surface orientation: effect of scene context

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The question of where we look within a visual scene has long been studied by monitoring fixation positions and their relationship to low-level (color, intensity, orientation, flicker and motion) and higher level (object-based, global depth or contextual) visual features in the image. Besides fixation location, the study of other saccadic parameters, especially saccade direction, can give new insight into (the preattentive mechanism of) overt attention. For simple slanted grid planes, spontaneous saccades follow the orientation of surface slant and tilt (a depth cue combination, as in conscious perception). This strategy may extend to complex scenes with natural stimuli. We test this assertion for two types of scene contexts (natural forest vs man-made urban). We examined eye movements and saccade direction in 16 observers while they free-viewed static color images over 7s. Observers' saccades were principally vertically and horizontally oriented for both conditions, but of importance, were more horizontally ($p<0.05$) and less vertically ($p<0.05$) oriented for urban than for forest context. In particular, the first saccades tended to follow the main horizontal and vertical directions of the scene and its ground surface orientation in depth: the slant. The saccade direction mechanism appears to be linked to either some low-level gradient or edge orientation, higher-level convergence of vanishing lines, or a more global gist contextual feature computation. This fast saccadic programming might rely on a visual mechanism to infer scene spatial layout: surface orientation, perspective, openness and scene category, in the absence of vestibular information. This result argues in favor of a feed-forward high-level scene representation, which could be accessed in parallel during the deployment of overt attention.

43.339 Pictorial Human Spaces: How Well do Humans Perceive a 3D Articulated Pose?

Elisabeta Marinoiu[1], Dragos Papava[1], Cristian Sminchisescu[2,1]; [1]Institute of Mathematics of the Romanian Academy, [2]Department of Mathematics, Faculty of Engineering, Lund University

When shown a photograph of a person, humans have a vivid, immediate sense of 3D pose awareness and a rapid understanding of the subtle body language, personal attributes, or intentionality of that person. How can this happen and what do humans perceive? How accurate are they? Our aim is to unveil the process and level of accuracy involved in 3D perception of people from images by assessing the human performance. Our approach to establishing an observation-perception link is to make humans re-enact the 3D pose of another person (for which ground truth is available), shown in a photograph, following a short exposure time of 5 seconds. Our apparatus simultaneously captures human pose and eye movements during the pose re-enacting performance. In the process of perceiving and reproducing the pose, subjects attend firstly upper body joints with a general trend of focusing more on extremities than internal joints. Although the resulting scanpaths are pose-dependent, they are quite stable across subjects both spatially and sequentially. Our study reveals that people are not significantly better at re-enacting 3D poses given visual stimuli, on average, than existing computer vision algorithms. Errors in the order of 10°-20° or 100mm per 3D body joint position are not uncommon. The contribution of our work can be summarized as follows: (1) the construction of an apparatus relating the human visual perception with 3D ground truth; (2) the creation of a dataset (publicly available) collected from 10 subjects, containing 120 images of humans in different poses, both easy and difficult, and (3) quantitative analysis of human eye movements, 3D pose reenactment performance, error levels, stability, correlation as well as cross-stimulus control, in order to reveal how different 3D configurations relate to the subject focus on certain features in images, in the context of the given task.

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43.340 Implicit measures of whether conceptual knowledge increases interest in photographs

Gabriela Duran[1, 2](gduran@uacj.mx), Mary A. Peterson[2, 3]; [1]Art Department, Universidad Autonoma de Ciudad Juarez, [2]Psychology Department, University of Arizona, [3]Cognitive Science Program, University of Arizona

Does conceptual knowledge regarding photographs, given by titles, increase viewers' interest in the photographs? Duran and Peterson (VSS 2013) asked observers to rate their interest in artistic photographs by John Gutmann with and without the artist's titles. Observers who saw photographs twice, first without a title and then a second time either with or without a title, rated them as more interesting on second presentation with a title. Other observers who were asked explicitly to indicate which areas of the photographs attracted their attention by placing squares around them placed more squares on photographs viewed with titles than without titles, indicating more areas of interest. Here we conducted a new experiment to assess interest implicitly while observers viewed photographs. Observers viewed 24 Gutmann photographs, half with the artist's titles and half without; title condition was blocked and counterbalanced across observers. They were asked to view the photographs for 5 seconds and afterwards to rate their interest on a four-point scale. While observers viewed the photographs, their eye movements were recorded to implicitly measure interest. We expected that observers would have more fixations on photographs with titles than without titles if they find the former more interesting. Results confirmed predictions: the average number of fixations was larger for the title condition (22.6) than the without-title condition (20.1), $p<.01$. Consistent with this finding, observers had shorter average dwell times on photographs with titles (1372 ms) than without tiles (1642 ms), $p<.01$. To create an implicit index of interest areas we identified areas with clusters of > 2 fixations or fixations > 600 ms. Consistent with last year's explicit measure there were more interest areas on photographs viewed with titles (46.2) than without titles (40.7), $p<.01$. At least as assessed implicitly by eye movements, conceptual knowledge increases interest in photographs.

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43.341 Eye fixations in video: Quantifying the effects of meaning and action on inter-observer convergence

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There has been significant recent interest in measuring neural and cognitive responses during dynamic scenes and video. In particular, it has been noted that the attention of different observers often synchronises, and that such moments can be identified when participants' eye fixations converge in space and time. The current studies aimed to establish whether convergence in fixation locations was associated with explicit self-reports of "important" moments. In two experiments, participants' eye movements were recorded while they watched a set of movie clips featuring a range of visual content. We developed a novel method for quantifying the inter-observer convergence, based on ROC analysis, and applied this method to find the moments when participants were most likely to be looking in the same place at the same time. These moments occurred more often than expected by chance, and were highest for clips involving action. Critically, there was a reliable correlation between inter-observer agreement and explicit self-reports of important moments, indicating that attention converged at meaningful times. Additional analysis of the visual and semantic content at fixation allows a data-driven approach to video, and provides a rich source of information for those investigating natural, active vision.

Acknowledgement: This work was supported by a British Academy Small Grant to TF (SG120844).

43.342 **The Look of Evil: How are Eye Movements Influenced by Film Comprehension?** John Hutson[1](jphutson@k-state.edu), Lester Loschky[1], Tim Smith[2], Joseph Magliano[3]; [1]Kansas State University, [2]Birkbeck University, London, [3]Northern Illinois University

Movies are ubiquitous and rapidly understood, but how does this occur? Voluminous reading research has investigated eye-movement/comprehension relationships, but do these relationships hold for film comprehension? We hypothesized film viewers' narrative event models would guide their attention while watching films. To test this, we manipulated the presence/absence of prior film context and measured resulting differences in film comprehension and eye-movements. We presented participants with one of two versions of the opening scene of Orson Welles' (1958) "Touch of Evil." In the Context condition, the clip opens with a bomb placed in a car trunk, the unknowing owners driving the car down the street, a couple (the protagonists) and numerous other people walking by the car on the street, and then the couple kissing with the car off-screen. The No-context condition was the same, but did not show the bomb placed in the car. The critical 3-minute portion of the clip was identical for both conditions, which differed only in seeing the bomb. In Exp 1, participants watched one of the two clips and then were asked what would happen next. We hypothesized that only Context condition viewers would mention an explosion. The results confirmed this hypothesis, with Context condition viewers far more likely to predict an explosion (76.2%) than the No-context viewers (8.3%), thus establishing a clear comprehension difference between the viewing conditions. Exp 2 was the same, but included eye-tracking. We hypothesized that viewers in the Context condition would fixate bomb-relevant details (the car and its trunk when on-screen) more than the No-context condition, showing the influence of film comprehension on eye-movements. Preliminary qualitative analyses support the predicted eye-movement differences between conditions, which are currently being quantified using dynamic region of interest analyses. Overall, preliminary results indicate that film viewers' comprehension does indeed influence their attention and eye-movements.

43.343 **What Would Jaws Do? The tyranny of film and the relationship between gaze and higher-level comprehension processes for narrative film.** Lester Loschky[1](loschky@ksu.edu), Adam Larson[2], Joseph Magliano[3], Tim Smith[4]; [1]Department of Psychological Sciences, Kansas State University, [2]Department of Psychology, University of Findlay, [3]Department of Psychology, Northern Illinois University, [4]Department of Psychological Sciences, Birkbeck University of London

What is the relationship between viewers' eye movements while watching a film and their comprehension of it? Most Hollywood movies can be considered "tyrannical" because they induce most viewers to look at the same things at the same time—hereafter, "attentional synchrony." But does this indicate that viewers also understand the movie similarly? To investigate this question, we manipulated the presence/absence of prior film context and measured resulting differences in film comprehension and eye movements. Viewers watched a 12-second James Bond movie clip, ending just as a critical predictive inference should be drawn that Bond's nemesis, "Jaws" would fall from the sky onto a circus tent. This was engendered by the filmmakers' use of cross-cutting between shots of Jaws falling through the air and shots of a circus tent. The No-context condition saw only the 12-second clip, but the Context condition also saw the preceding 2.5 minutes of the movie, thus providing them with a mental model of the prior narrative context before seeing the critical 12-second portion of the clip. Overall, there was strong attentional synchrony for all viewers in both viewing conditions. However, the No-context viewers were significantly less likely to draw the critical inference (i.e., less understanding), were more likely to consider the first shot of the circus tent to be a new event (i.e., less perceived coherence across cross-cut shots), showed less attentional synchrony during the first circus tent shot (i.e., a greater need to explore the scene) and had a greater probability of fixation on the first circus tent shot (i.e., greater processing difficulty). Thus, despite Hollywood films' "tyrannical" control of viewers' attention, viewers' subtle eye movement differences can indicate important comprehension differences. These results point to the need for a theory encompassing processes involved from the perception to the comprehension of a film.

43.344 **Predicting observers' task from their scanpaths on natural scenes** Ali Borji[1](borji@usc.edu), Laurent Itti[1,2]; [1]Department of Computer Science, University of Southern California, [2]Departments of Neuroscience and Psychology, University of Southern California

In an influential yet anecdotal illustration, Yarbus suggested that human eye movement patterns are modulated top-down by different task demands. While the hypothesis that it is possible to decode the observer's task from eye movements has received some support (e.g., Iqbal & Bailey (2004); Henderson et al. (2013)), recently Greene et al. (2012) argued against it by reporting a failure. Here, we perform a more systematic investigation of this problem and probe a larger number of experimental factors than previously. Our main goal is to determine the informativeness of eye movements for task and mental state decoding. We argue that task decoding accuracy depends critically on three factors: 1) spatial image information, 2) classification technique, and 3) image and observer idiosyncrasies. We perform two experiments. In the first experiment, we re-analyze the data of Greene et al. (2012) and contrary to their conclusion, we report that it is possible to decode the observer's task from aggregate eye movement features slightly but significantly above chance, using a Boosting classier (34.12% correct vs. 25% chance-level; binomial test, $p = 1.07$ e-04). In the second experiment, we repeat and extend Yarbus' original experiment by collecting eye movements of 21 observers viewing 15 natural scenes (including Yarbus' scene) under Yarbus' seven questions. We show that task decoding is possible, also moderately but significantly above chance (24.21% vs. 14.29% chance-level; binomial test, $p = 2.45$ e-06). We also find that task decoding accuracy is higher for images that contain more relevant information to answer the questions than for other images. Thus, we conclude that Yarbus' idea is supported by our data and continues to be an inspiration for future computational and experimental eye movement research. From a broader perspective, we discuss techniques, features, limitations, societal and technological impacts, and future directions in task decoding from eye movements.

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43.345 **Does an interaction catch the eye? Decoding eye movements to predict scene understanding** Gregory Zelinsky[1,2](Gregory.Zelinsky@stonybrook.edu), Hossein Adeli[1]; [1]Department of Psychology, Stony Brook University, [2]Department of Computer Science, Stony Brook University

Can eye movements made during scene viewing be decoded to predict how a scene will be understood? Participants (n=15) freely viewed a scene for 100ms, 1000ms or 5000ms, then freely described the scene that was just viewed. All 96 scenes depicted two people in various contexts, but were divided into interacting and non-interacting conditions depending on whether a given participant mentioned an interaction in their description. Scenes were manually segmented into objects and fixations were associated to described segments. The probability of fixating an object given it was described was .8 after 5000ms of viewing, higher than the .52 probability after 1000ms viewing. There were no significant differences between interacting/non-interacting conditions. The probability of describing an object given its fixation was lower (.58, averaged over conditions) and did not depend on interaction condition or viewing time. These patterns suggest that some objects must be fixated to be described, and that 1000ms of viewing did not always provide this opportunity. The probability of mentioning an interaction was also lower with 100ms viewing, further suggesting a role of fixations in scene understanding. To explore whether sufficient information exists in fixation behavior to predict whether a scene would be described as interacting we derived 22 gaze features capturing the order in which key object types were fixated and used these features to train an SVM classifier. Interaction classification was above chance (64%), indicating that this high-level scene understanding could be determined solely from fixation behavior. Further analysis revealed that fixations on a person or fixations between people are predictive of an interaction description, and fixations on objects or between objects and people are predictive of a non-interaction description. Not only are eye movements important to achieve deeper levels of scene understanding, they can be decoded to predict how a scene will be understood.

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43.346 **Statistics of Eye Movements in Natural Tasks** Brian Sullivan[1](brians@ski.org), Saeideh Ghahghaei[1], Laura Walker[1]; [1]Smith-Kettlewell Eye Research Institute

Research in our lab has been concerned with the statistics of saccade lengths and fixation durations during free viewing of natural images. However, such experiments consist of 2-D displays with the head fixed. It is not obvious that findings in this domain should generalize to natural scenarios. Bahill, Adler and Stark (1975) examined the statistics of saccade length while participants walked outdoors wearing a mobile eye tracker, but there has been no subsequent effort to replicate these findings with modern eye trackers, with more statistical analyses, and in a wider range of natural tasks. To address this, we used a mobile eye tracker to capture eye movements of participants while in engaged in a set of common tasks including: Making a sandwich, playing Frisbee, transcribing a piece of text into a

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word processor, navigating an office hallway, and navigating a city street. Eye-in-head position data were median filtered and segmented by a 35°/s velocity threshold and separated into saccades and fixations. We analyzed saccade length, duration and orientation, and fixation duration. We present preliminary data from a set of normally sighted subjects. Over the course of ~25 minutes total, subjects made an average of ~3000 fixations. Saccade lengths peaked at ~3-6° degrees with a heavy tail typically ranging out to about 40°, but also including some larger saccades. We replicate Bahill et al and find that ~85% of saccades are under 15°. Additionally, while saccades occur in all directions, the orientation of saccade trajectories is generally biased towards the cardinal directions, occurring roughly twice as often as other orientations. Fixation durations had a median of ~400ms with a long tail with extending out to ~4-5s. This data set provides a reference for normative human eye movement behavior in non-constrained circumstances.

43.347 **Predicting the task from eye movements using multivariate pattern analysis** Grigori Yourganov[1,2], Marc Berman[1,2], John Henderson[1,2]; [1]Department of Psychology, University of South Carolina, Columbia, SC, USA, [2]Institute for Mind and Brain, University of South Carolina, Columbia, SC, USA

In our study, we investigated the use of multivariate pattern analysis to predict a subject's viewing task from their eye movements. Previous research indicates that prediction is possible if the visual stimuli are different across tasks (Henderson, Shinkareva, Wang, Luke, & Olejarczyk, 2013). However, one study suggests that if the same stimuli are used in all tasks, prediction is no better than random guessing (Greene, Liu, & Wolfe, 2012). To investigate this question further, we recorded eye movements from 72 subjects performing 3 tasks on the same set of real-world visual scenes: 1) a visual search task, 2) a scene memorization task, and 3) an aesthetic evaluation task. A set of classifiers (linear and nonlinear, univariate and multivariate) was used to predict the task for a particular trial using 7 features of eye movements recorded during this trial (number of fixations; mean, standard deviation, and skewness of fixation durations and of saccade amplitudes). All classifiers were successful in predicting the task when trained on the other trials recorded from the same subject. Linear classifiers, particularly Fisher's linear discriminant (FLD), were also successful in predicting the task for each subject when the training data came from the other subjects (mean prediction accuracy of FLD was 56%, with random guessing corresponding to 33%). These results suggest that the homoscedastic multivariate Gaussian model effectively captures predictive eye movement information that is specific to a task and generalizes across subjects. For each pair of tasks, we computed the loadings of each of our Z-scored features to determine the importance of each feature in predicting the task. The two most relevant features, on average, were the number of fixations and the mean saccade amplitude. The skewness of saccade amplitudes was the least important, but still contributed to prediction.

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43.348 **Oculomotor behavior of expert and novice geologists in the field** Jeff B. Pelz[1,4](pelz@cis.rit.edu), Tommy P. Keane[1,4], Karen M. Evans[4], Kate Walders[1,4], John A. Tarduno[2,5], Robert A. Jacobs[3]; [1]Carlson Center for Imaging Science, College of Science, Rochester Institute of Technology, [2]Department of Earth and Environmental Sciences, University of Rochester, [3]Department of Brain and Cognitive Sciences, University of Rochester, [4]Multidisciplinary Vision Research Laboratory, Rochester Institute of Technology, [5]Paleomagnetic Research Group, University of Rochester

It is now possible to collect gaze data from mobile observers as they perform complex tasks in natural, outdoor environments (Evans, et al. 2012). Analyzing the data from multiple observers collected during relatively unconstrained tasks is still a very challenging problem. We monitored the gaze of thirteen geologists (seven student novices and six experts) as they viewed a geological site in Death Valley, CA for 90 seconds before answering a question about the tectonic, volcanic, or glacial activity responsible for the features present in the scene. Synchronized digital video records of each observer's right eye and from a scene camera attached directly above the tracked eye were saved for offline calibration and analysis. The video from one of the experts was unusable due to excessive squinting. The remaining observers had valid gaze data for 50 – 85% of the trial (an average blink rate would yield ~87% valid gaze data with no track loss). Eye and scene video for the remaining twelve observers was calibrated and analyzed. Valid Fixations (defined in scene rather than head coordinates to allow fixations in the presence of VOR) were detected using a dispersion algorithm, and distributions for each observer's fixation duration, saccade amplitude, and saccade direction were computed. The expert geologists' mean fixation durations were significantly shorter than the novice's (232 vs. 286 msec; α <0.05) and their mean saccade lengths tended to be shorter (4.03 vs. 4.58 deg; α <0.09). There was no variation in the angular distribution of their saccades. Further analyses of the extended spatiotemporal fixation patterns are ongoing. While none of the experts had seen the geological site before the experiment began, expertise and content-area knowledge influenced even low-level oculomotor behavior.

Acknowledgement: This work is supported by NSF 0909588.

43.349 **Predicting eye movements of rhesus monkeys searching for pedestrians in natural images** Mark Segraves[1](m-segraves@northwestern.edu), Sara Caddigan[1], Ren-Shuoh Kuo[1], Konrad Kording[2]; [1]Dept. of Neurobiology, Weinberg College of Arts & Sciences, Northwestern University, [2]Depts. of Physical Medicine & Rehabilitation, and Physiology, Feinberg School of Medicine, Northwestern University

Models developed to predict human search behavior in natural environments rank a potential eye movement target based upon at least 3 factors: bottom-up salience (salience), similarity to the search target (relevance), and environmental features that predict where the object might be found (context). A model that combines all 3 of these factors provides accurate prediction (~90%) of eye fixations when human subjects perform a naturalistic search task - searching for pedestrians in images of urban landscapes (Ehringer et al. 2009). It is essential to develop similar models to predict search behavior in the rhesus monkey, the preeminent model for investigating the neural mechanisms involved in eye movement control. For these experiments, 2 monkeys were trained to perform a pedestrian search task identical to the task used for human subjects. Monkey eye movement behavior was then compared to the predictions of the same models developed by Ehringer and colleagues to predict human behavior. Salience, relevance, and context models were all predictive of monkey eye fixations, and the combined model was accurate to a level that approached that for human behavior (~80%). A novel finding of these experiments is the suggestion that rhesus monkeys use scene context to guide their search. We attempted to disrupt the influence of scene context on search by testing the monkeys with an inverted set of the same images. Surprisingly, the monkeys were able to locate the pedestrian at a rate similar to that for upright images (68% upright; 64% inverted). Image inversion did not affect the predictive power of the salience model. Predictions of the relevance and context models, however, were near chance for the inverted images. The predictive power of these models for monkey search behavior informs future studies to understand the neural mechanisms responsible for eye movement control during search in natural environments.

Acknowledgement: National Eye Institute

43.350 **Microsaccades and drift are similarly modulated by stimulus contrast and anticipation** Yoram Bonneh[1](yoram.bonneh@gmail.com), Moshe Fried[2], Amos Arieli[3], Uri Polat[2]; [1]Department of Human Biology, University of Haifa, Israel, [2]Goldschleger Eye Research Institute, Tel-Aviv University, Israel, [3]Department of Neurobiology, The Weizmann Inst. of Science, Rehovot, Israel

Microsaccades are considered to be involuntary fixational eye movements in addition to a slower random-walk like movement called drift. Following a perceptual event, as well as prior to anticipated events, the microsaccades are typically inhibited and later released in a time course that depends on stimulus properties and cognitive factors. We examined whether the drift also follows the same inhibitory pattern. Method: During fixation observers (n=16) viewed passively a sequence of randomly ordered Gabor patches with varied contrast flashed every 1 second. In a second experiment, observers (n=22) performed a continuous performance task (CPT) with stimuli presented every 2 seconds. The time courses of microsaccade rate, pupil size and drift amplitude were computed relative to stimulus onset based on high speed eye tracking data. Drift was computed after filtering out all traces of saccades, using "box-counting" and the position range within a sliding window. Overall, ~20,000 trials were examined. Results: The drift time course was similar to that of microsaccade rate, though with larger variability. It showed a similar dependence on contrast, and on the history of preceding events. Drift inhibition was correlated with microsaccade inhibition across individuals in the pre-stimulus period of the CPT. Moreover, it persisted in trials with no microsaccades, ruling out an indirect effect of microsaccades on drift. To minimize the possible crosstalk artifact of large pupil size changes on position, we analyzed iso-luminance stimuli as well as pre-stimulus periods. In these conditions, we found no correlation between the pupil derivative and drift, suggesting a genuine drift effect. Conclusion: The drift, like microsaccades and perhaps other types of

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body movement, appears to show a "freeze effect" in response to perceptual events as well as prior to anticipated events. The pattern of this effect conveys information on the time course of the cognitive processes involved.

Spatial vision: Crowding and eccentricity

Monday, May 19, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

43.401 The two-dimensional shape of the crowding zone following macular lesions

Susana Chung[1](s.chung@berkeley.edu), Jean-Baptiste Bernard[1,2], Girish Kumar[1], Anirvan Nandy[3], Bosco Tjan[4]; [1]University of California, Berkeley, [2]LPC, CNRS, Marseille, [3]The Salk Institute for Biological Studies, [4]University of Southern California

The crowding zone, the region over which spatial interaction of nearby objects occurs, is known to be isotropic in shape in the normal fovea, and anisotropic in the normal periphery, with the major axis oriented toward the fovea. Recently, Nandy and Tjan (2012) attributed the anisotropic shape of the crowding zone in the normal periphery to saccadic eye movements. A prediction from their theory is that people whose saccadic eye movements are referenced to a non-foveal retinal location should show corresponding changes in the shape of the crowding zone at this location, and at other peripheral locations. To test this prediction, we mapped the two-dimensional shape of the crowding zone for three observers with macular lesions who demonstrated a consistent re-referencing of saccades toward their non-foveal preferred retinal locus (PRL), at their PRL and at another peripheral (para-PRL) location. To map the crowding zones, we determined the critical spacing between a target letter (presented at the PRL or at a fixed para-PRL location) and its flankers that yielded 71% correct identification of the target letter, along different meridians with respect to the target. Stimuli were presented using a scanning laser ophthalmoscope that allowed us to present stimuli at precise retinal locations while obtaining behavioral responses from the observers. Our results showed that for all observers, the crowding zone at the PRL was significantly less anisotropic than would be expected based on the normal periphery. At the para-PRL location, the crowding zone was irregular in shape, but could be well described by two superimposed ellipses with one oriented toward the PRL and the other toward the non-functioning anatomical fovea. Our results provide the first set of psychophysical evidence linking the re-referencing of saccadic eye movements with the modification of spatial properties at and around the PRL for people following macular lesions.

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43.402 The size of population receptive field in V2 and crowding effect

Peng Cai[1](caipeng1980@gmail.com), Dongjun He[1], Fang Fang[1,2,3]; [1]Department of Psychology and Key Laboratory of Machine Perception (Ministry of Education), Peking University, [2]Peking-Tsinghua Center for Life Sciences, Peking University, [3]IDG/McGovern Institute for Brain Research, Peking University

Crowding is the identification difficulty for a target in the presence of nearby flankers. Based on psychophysical findings, many theories have been proposed to explain crowding at multiple levels. However, the neural mechanism of visual crowding is largely unknown. Here, we used the fMRI-based population receptive field (pRF) technique to probe this issue. A target was centered at 6.25° eccentricity with two adjacent flankers positioned radially. The target and flankers were a circular patch of a sine-wave grating (radius: 1.25°; contrast: 1.0; spatial frequency: 2 cycles/°; orientation: -45° or 45°) and were presented in a uniform gray background. They rotated round the fixation point and were displaced 20° every 2 seconds. The orientation of the flankers could be either perpendicular or parallel to that of the target, which resulted in a weak or strong crowding effect, as confirmed by a separate psychophysical test. We acquired BOLD signals responding to the rotating stimuli, and then estimated the pRF of each voxel in early visual areas in the weak and strong crowding conditions. . We found that, for the voxels in V2 responding to the target, their mean pRF size was significantly smaller in the weak crowding condition than that in the strong crowding condition. Such a pRF size difference was closely associated with subjects' attention. The difference completely vanished when subjects performed a demanding fixation task. We speculate that the pRF size reduction might serve to prevent interference from the flankers and consequently weaken the crowding effect. Attention might play a significant role in this process.

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43.403 EEG frequency tagging dissociates target and flanker processing in crowding

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Flankers can strongly deteriorate performance on a target (crowding). The neural mechanisms of crowding are largely unknown. We have recently shown that the N1 component of the EEG is suppressed during crowding. Because it is difficult to disentangle the neural correlates of target and flanker processing with standard visually evoked potentials, here, we used a frequency-tagging technique to analyze EEG responses separately for flankers and target. Subjects discriminated the offset direction of a vernier that was slowly increasing in size either to the left or right. The vernier and the flankers were either green or red and flickered at two different frequencies. Flankers of the same color as the vernier (green-green or red-red) crowded more strongly than flankers of a different color (green-red or red-green) because the former, as we propose, grouped with the vernier. EEG responses to the vernier were suppressed during crowding (same color flankers) compared to uncrowding (different color flankers). EEG responses to the flankers were slightly larger when the flankers grouped with the target compared to when they ungrouped from the target. Hence, EEG frequency tagging dissociates target and flanker processing. Our results suggest that, in crowding, the target is suppressed when it groups with the flankers while flanker-related activity increases or stays constant.

43.404 Crowding and Visual Field Inhomogenieties

Jennifer Anderson[1](jander22@uic.edu), E. Leslie Cameron[1,2], J. Jason McAnany[1,3], Michael Levine[1,4]; [1]Psychology, University of Illinois at Chicago, [2]Psychology, Carthage College, [3]Ophthalmology and Visual Sciences, University of Illinois at Chicago, [4]Laboratory of Integrative Neuroscience, University of Illinois at Chicago

For many visual tasks, performance across the visual field is asymmetric – typically best along the horizontal meridian (HM) and worst directly above fixation (North). However, this phenomenon has not been examined within a crowding paradigm. Our purpose was to investigate visual field asymmetries in a crowding task by determining how crowder configuration affects threshold throughout the visual field. Crowding thresholds were measured across eight isoeccentric visual field locations in a target discrimination task: Experiment 1 measured crowding threshold for a target within a symmetric ring of crowders, Experiment 2 tested various subsets of this ring. We were interested in how well targets could resist crowding, thus results are reported in terms of "robustness", the inverse of the crowding threshold (1/crowding threshold). Visual field data were fit with ellipses. In Experiment 1, robustness was strongest along the HM and weakest at North and the presence of visual field asymmetries was confirmed. In Experiment 2, the largest differences in visual field robustness patterns were observed when crowders were "between" or "outside" the target and fixation. When "outside" (i.e., crowders at greater eccentricity than the target), visual field patterns indicated high levels of robustness along the HM and robustness data were well fit by a somewhat flattened ellipse. When "between" (i.e., crowders located between fixation and target), the mean robustness of the HM was equivalent to that of the vertical meridian (VM). However, robustness was weak at North and strong at South, presenting an effective "shift" along the VM. These data demonstrate that visual field asymmetries exist even in the context of crowding stimuli. However the specific asymmetric pattern depends upon the configuration of the crowders relative to both the target and fixation. In particular, processing along the vertical meridian is unique, and crowder configuration can either inhibit or enhance robustness.

43.405 Visual acuity and spatial interaction zones: investigating the periphery in anisometropic amblyopia

M Izzuddin Hairol[1,2](izzuddin.hairol@anglia.ac.uk), Norazizah Abd-Latif[2], Pui Juan Woi[2], Nurul Hafizah Ahmad-Rashaidi[2], Sharanjeet Kaur[2], Sarah J Waugh[1]; [1]Anglia Vision Research, Department of Vision and Hearing Sciences, Anglia Ruskin University, Cambridge, U.K., [2]Program Optometri & Sains Penglihatan, Universiti Kebangsaan Malaysia, Kuala Lumpur, Malaysia

Anisometropic amblyopia is often simulated in healthy individuals by imposing blur and measuring foveal visual acuity. We examine (1) acuity and the shape of spatial interaction zones at the fovea and in the periphery, in normal participants and anisometropic amblyopes and (2) the effect of imposed blur on acuity at different eccentricities in normal participants to compare with the amblyopic periphery. Acuity was measured using a Method of Constant Stimuli and Sheridan-Gardiner letters in 6 normal and 6 amblyopic participants. Crowding was assessed by comparing performance for a letter flanked by other letters placed at horizontal, vertical and oblique orientations. Stimuli were presented foveally and at 2.5, 5 and 10deg in the lower visual field. In addition, foveal acuity of 4

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different normal participants was blurred to match the mean amblyopic acuity using Gaussian (σGaussian 4-6 arcmin) and optical defocus. Letter acuity was then measured across the lower visual field. Anisometropic amblyopes exhibit asymmetric crowding regions, similar to normal, at all locations. At the fovea, crowding extent is ~1.2× bigger horizontally, whereas in the periphery it is ~1.6× bigger vertically. Crowding depth for both groups is consistently larger when target and flankers are arranged vertically, than horizontally (0.3-2.0×; p<0.05). Without blur, normal participants show larger acuity deterioration with increasing eccentricity (E2 of 2.1±0.2) than do anisometropic amblyopes (E2 of 7.7±2.3). With Gaussian blur, normal participant acuity across eccentricity is not significantly different from that found for the anisometropic amblyopes (p=0.91; E2 of 6.3±0.8). Optical defocus reveals similar E2 results. Anisometropic amblyopia demonstrates similar horizontal-vertical asymmetry of crowding regions to those found in normal vision, i.e., generally larger crowding for target arrangements radial to the fixation point. Foveal acuity in anisometropic amblyopia is worse due to increased intrinsic blur relative to normal vision; however their periphery appears to be functionally normal.

Acknowledgement: Ministry of Education Malaysia

43.406 **Accuracy in Localising the Centre of a Circle** Hongfan Shen[1](hfshen@korea.ac.kr), Damien Mannion[2,3], Seong-Whan Lee[1], Daniel Kersten[1,3]; [1]Department of Brain and Cognitive Engineering, Korea University, [2]School of Psychology, University of New South Wales, [3]Department of Psychology, University of Minnesota

In everyday life, humans can point to, or aim at, the centre of an object with apparent ease. However, accurately locating an object's centre is computationally challenging due to the inherent complexity of the object's representation in the visual image and the spatial uncertainty of the object's boundaries. Here, we probed the accuracy of human observers in estimating the centre of a simple circle. Participants (n=10) were presented with a circular contour defined by a set of dots, and were asked to translate the dots such that the centre of the circle was aligned with a visible target point. To probe observer prformance, we manipulated the number of dots defining the contour (8, 32, or 128), the size of the circle (3, 6, or 18 deg visual angle), and the level of radial position noise applied to the dots (drawn from a Gaussian with a standard deviation of 1%, 3%, 10%, or 30% of the circle radius). Observer estimation error was well captured by a function that quantified performance in terms of the radial position noise in the stimulus, the observer's internal noise, and the number of dots utilised by the observer. We find that the estimates of internal noise increased approximately linearly with increasing circle size, while being roughly equivalent for different numbers of dots. This appears consistent with an increased positional uncertainty in the periphery of the visual field. Conversely, the estimates of the number of utilised samples increased with number of dots but was roughly constant across circle size. Overall, this study represents a quantification of human performance on a simple centroid localisation task that will allow for future comparisons with ideal and sub-ideal observers to understand the computational underpinnings of this important visual capacity.

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43.407 **Random-sampling leads to multiplicative noise in crowded displays** Carl Gaspar[1,2](ccbd.gaspar@yahoo.co.uk), Wei Chen[1,2]; [1]Center for Cognition and Brain Disorders, Hangzhou Normal University, [2]Zhejiang Key Laboratory for Research in Assessment of Cognitive Impairments

Is crowding stochastic? Dakin, Cass, Greenwood and Bex (2010) show that their crowding results are consistent with a model that assigns random weights to multiple flanking elements. If observers are judging the orientation of a peripheral Gabor target, then this random-sampling model predicts that internal noise should increase with the variance of flanker-orientation – a form of multiplicative noise. We tested this hypothesis directly by measuring the effect of flanker-orientation variance on response consistency in a 2AFC orientation discrimination task. 2 observers (Burgess & Colborne, 1988) identified which of 2 peripheral Gabor patches (2.5 degrees eccentricity), surrounded by 8 Gabor flankers, was tilted (clockwise or counterclockwise from horizontal). Target-orientation was varied using method-of-constant-stimulus, and an exact copy of each stimulus was shown in repeated trials (same target-orientation and configuration of flanker orientations). Orientation thresholds and response-consistency were measured separately for various levels of flanker-orientation variance (3 levels in Observer 1, spanning an 8-fold range; and 4 levels in Observer 2, spanning a 16-fold range). Critically, the mean of flanker orientation was always 0 (horizontal) for every stimulus; performance could only be affected by flanker variance. For both observers, orientation thresholds increased with flanker variance by a log-log slope of 1/2. Most importantly, response-consistency data for both observers show that the slope between proportion-correct and proportion-agreement reached an upper asymptote at the highest flanker variance, which is the signature of muliplicative noise and consistent with the model of random-sampling suggested by Dakin et al. (2010). In a current experiment we are varying the number of flankers as well as their orientation-variance, and predict that a random-sampling model can be well fit to all these data.

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43.408 **The neural correlate of the polarity advantage effect in crowding** Ziyun Zhu[1](zzyladette.aicfc@gmail.com), Fang Fang[1,2,3]; [1]Department of Psychology and Key Laboratory of Machine Perception (Ministry of Education), Peking University, Beijing 100871, China, [2]Peking-Tsinghua Center for Life Sciences, Peking University, Beijing 100871, China, [3]PKU-IDG/McGovern Institute for Brain Research, Peking University, Beijing 100871, China

If the target in a crowding display differs from the flankers in its contrast polarity, the extent of crowding is reduced compared to the condition where the target and flankers have the same polarity. This phenomenon is referred to as the polarity advantage effect. Here, we investigated its neural mechanisms using event-related potentials (ERPs). A target was centered at 8° eccentricity in the upper-left visual quadrant, either alone or with two adjacent flankers positioned radially. The target and flankers were a circular patch of a sine-wave grating and were presented in a uniform gray background. They were rendered in black or white. They could have the same or opposite polarities. Only in the same polarity condition, there was a significant crowding effect as manifested by orientation discrimination impairment with the target. We measured the earliest ERP component (C1) evoked by five stimulus configurations, including the target only, the target with the flankers of same polarity, the target with the flankers of opposite polarity, the flankers of same polarity only, and the flankers of opposite polarity only. The C1 had a peak latency of about 80 ms and is believed to be generated in early visual cortical areas (i.e. V1 and V2). We found that, the sum of the C1 amplitudes evoked by the target and the flankers was smaller than the C1 amplitude by the target with the flankers, suggesting a mutual cortical suppression between the target and flankers. Importantly, the suppression was significantly stronger when the target and flankers had the same polarity than when they had opposite polarities. We also found that the suppression depended on subjects' spatial attention to the stimuli. These results suggest that the early cortical suppression enabled by spatial attention might contribute to the polarity advantage effect in crowding.

Acknowledgement: This work was supported by the Ministry of Science and Technology of China (2011CBA00400 and 2010CB833903) and the National Natural Science Foundation of China (Project 30925014 and 31230029).

43.409 **The Time Course of Crowding Following a Change in Target Orientation** Jeffrey Nador[1](jeff_nador@hotmail.com), Yury Petrov[1], Adam Reeves[1]; [1]Department of Psychology, College of Science, Northeastern University

Previous research suggests that targets remain uncrowded when at least one feature distinguishes them from their flankers (Poder, 2006). While spatial properties of crowding have been studied in detail, the time course of crowding remains unknown. The present research studies the time course of crowding, using a new cueing paradigm. On each trial, observers were shown a ring of 20 Gabors oriented radially or tangentially to the ring; the ring radius was 10°. Each Gabor was flanked by 4 plaids containing both radial and tangential components. After a 1s preview, half the Gabors (randomly chosen) changed their orientation by 90° and one among those was then spatially cued with a variable delay (0 - 800 ms). Our observers' task was to report whether the cued target Gabor's new orientation was radial or tangential to the ring. Our results indicate that target identification slowly degrades with cue latency, suggesting that following its appearance the target Gabor is initially not crowded and that crowding onsets at approximately 1 d' / s. Such a slow onset is quite remarkable, and sets a constraint on possible mechanisms of crowding. For example, early vision suppression phenomena happen an order of magnitude faster (Petrov & McKee 2009). We hypothesize that while spatial attention alone has insufficient resolution to isolate the target, the target appearance creates a transient motion signal, which could be used by feature and spatial attention combined to isolate the target from its flankers. As the motion signal extinguishes, the enhanced attentional resolution due to motion popout is lost and crowding gradually sets in.

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43.410 Motion-priming in crowding: evidence for motion averaging
Andrea Pavan[1](andrea.pavan@psychologie.uni-regensburg.de), Martin Gall[1], Mark W. Greenlee[1]; [1]Institute of Experimental Psychology, University of Regensburg

When a target object is presented in peripheral vision and flanked by similar objects, the specific information carried by the target is no longer available to the observer. This form of inhibitory interaction between target and flankers is known as visual crowding. However, though the information carried by the target is not available in crowding, important target features may still be processed. There is psychophysical evidence that (low-level) priming, e.g., from oriented gratings (Faivre, & Kouider, 2011. Journal of Vision, 16, 1-13) as well as high-level semantic priming (Yeh, et al., 2012. Psychological Science, 23, 608-616) survive crowding. In the present study we report motion-priming effects in the non-crowded condition across all prime durations employed (i.e., 200, 500, 1000 and 2000 ms), showing its exponential decay as the prime duration increases. We also show that motion priming for globally translating dots does not survive crowding at any of the prime durations tested. Further experiments suggest that the absence of motion priming in the crowded condition does not depend on the lack of focused attention on the crowded prime. Indeed, pre-cueing the prime did not restore the priming effect. Several studies (see Levi D. M., 2008. Vision Research, 48, 635-654) suggest that crowding depends on the presence of large receptive fields in the retinal periphery. If target and flankers fall within the same receptive field the specific target information is suppressed, while the information of flankers and target is averaged. In a third experiment we showed that when a certain percentage (e.g., 40%) of flankers moved in the same motion direction as that of the prime, the priming effect was restored. Taken together these results suggest that in crowding motion signals are averaged, and such pooling is likely to be pre-attentive (Parkes, et al., 2001. Nature Neuroscience, 4, 739-744).

43.411 Spatial and temporal crowding with normal observers
Shira Tkacz-Domb[1](shirtzi@yahoo.com), Einat Rashal[1], Yaffa Yeshurun[1]; [1]Psychology Department, University of Haifa

Spatial crowding refers to impaired target identification when it is surrounded by other stimuli in space. Temporal crowding refers to impaired target identification when it is surrounded by other stimuli in time. When temporal and spatial crowding were measured in the fovea they were interrelated with amblyopic observers but almost absent with normal observers. This study examined whether a reliable temporal crowding can be found for normal observers with peripheral presentation, and whether similar relations between temporal and spatial crowding will emerge. In three experiments, an RSVP of 3 displays was presented at 9° of eccentricity. Each RSVP's display included 1 (Experiment 1) or 3 (Experiments 2 & 3) letters. One of these displays included a target – an oriented T. Observers indicated the T's orientation. The ISI between the displays was systematically manipulated. Additionally, to determine the extent of spatial and temporal crowding simultaneously, in Experiments 2 & 3 the spacing between the target (the central letter) and its flankers was independently manipulated. As expected, we found spatial crowding: accuracy improved as the target-flankers spacing increased. This spatial crowding significantly interacted with target temporal position with in the RSVP stream, showing increased accuracy rates with later target positions. Critically, we also found temporal crowding in all 3 experiments: accuracy increased as the ISI between the displays increased. This effect was found even when only ISIs that are equal or larger than 150 ms were included, ensuring this ISI effect goes beyond basic backward or forward masking. Interestingly, the extent of this temporal crowding was larger for smaller target-flankers spacing (but only in Experiment 2), and was more pronounced when the target appeared at the first display. Hence, when the stimuli are presented at peripheral locations both spatial and temporal crowding can be demonstrated with normal observers.

43.412 Investigating visual crowding of objects in complex scene images
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Visual crowding describes impaired object recognition in peripheral vision due to the presence of other nearby objects. Previous studies of crowding have largely utilized letters, numbers, or Gabors as stimuli on blank backgrounds (Strasburger, Harvey & Rentschler, 1991; Greenwood, Bex, & Dakin, 2010). Additionally, crowding has more recently been demonstrated using objects as stimuli (Wallace & Tjan, 2011). The present study investigated crowding using objects in real world scenes. Virtual living-room scenes were created. Target objects were placed at 12o retinal eccentricity from fixation. In the crowded condition, four distractor objects were placed at a distance less than the critical spacing from the target, where crowding would be induced as estimated by Bouma's constant. In the uncrowded condition, the same four distractor objects were placed farther than the critical spacing from the target, where crowding would not be expected to occur. In Experiment 1, the location of the target object was exogenously cued and the image was flashed for 80 ms followed by a neutral gray screen. Participants responded to the target object's category with a 12-AFC response (including all objects shown in all versions of the scene). Experiment 2 used eyetracking to ensure participants were centrally fixated at the beginning of each trial. Procedures were similar to the first experiment, but with the image remaining on the screen for one eye fixation. In both experiments, object recognition performance was significantly reduced for crowded targets as compared to uncrowded targets. Participants who experienced a stronger crowding effect were more likely to incorrectly select a distractor object that was present in the scene versus a random object not shown, consistent with the idea that crowding involves confusion of the target and distractors. This study is unique in that it rigorously shows crowding of multiple objects in multiple real world scenes.

43.413 The roles of letter exposure and letter frequency in learning to identify crowded letters
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Crowded letter recognition can be enhanced by training on character-based tasks or by non-task-based training (stimulus exposure only). Here, we asked whether the variation in learning benefits across training methods can be accounted for by stimulus-dependent factors such as letter exposure, English-language letter frequency, and letter spatial complexity. We analyzed the data of four training groups sourced from two learning studies (Yu, Legge et al., 2010; Yu, ARVO 2013). All groups completed pre- and post-tests including a letter-recognition task (identifying trigrams, strings of three random letters, presented at varying distances left and right of the midline 10° below fixation). Training comprised four or five daily one-hour sessions. The four training methods are trigram training (identifying three letters), lexical-decision training (discriminating three-letter words from non-words), task-absent trigram exposure with repetition (having the option of repeating the same trigram stimulus for as many times as needed), and task-absent trigram exposure without repetition. We modeled post-pre improvement of crowded letter recognition (examining middle letter of the trigrams only) as a function of letter exposure, frequency, complexity, and the interaction terms. The best-fit model ($p<.0001$; $R2=.19$) included two significant predictors—letter exposure, and interaction of exposure and frequency. Across training groups and individual letters, letter exposure ranged from 0 to 3515 occurrences. Letter frequency ranged from 0.09% to 12.55% (Jones & Mewhort, 2004). The model suggests that despite differences in training protocols across groups, globally, letter exposure is the best predictor of post-pre improvement (positive correlation) among the variables investigated, and that the slope for exposure is varied depending on letter frequency (negative correlation). Our results indicate that perceptual learning protocols can benefit from taking into account the amount of letter exposure and letter frequency.

43.414 Perceptual learning reduces identity errors but not position errors in visual crowding
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A letter or object target when flanked by additional letters or objects becomes difficult to recognize in peripheral vision. Recent studies show that perceptual learning can reduce this crowding effect. In crowding, the target errors may be contributed to identity errors as well as position errors in that the central target is frequently reported to a flanker position (Zhang et al., 2012). In addition, flankers are often reported to the target position (Strasburger et al., 2005), although it is unclear whether these flanker reporting errors are the cause or result of crowding. In this study we investigated how the target identity and position errors, and the flanker reporting errors, are associated with crowding perceptual learning. Observers were trained to report the central target presented at 8o retinal eccentricity (partial report). Before and after training they also reported all three letters (whole report). The results show: (1) Five sessions of training reduced target recognition threshold by 33.6% in partial report tasks, suggesting reduced crowding via perceptual learning. (2) The target identity errors revealed by whole report tasks were reduced significantly except with smallest letters where crowding was the strongest. (3) However, the target position errors, defined by the ratios between actual and predicted whole report rates, were unchanged after normalized by target identity rate changes. (4) In addition,

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in partial report the flanker reporting errors when normalized by target reporting rates were unchanged after training. Perceptual learning reduces visual crowding by lowering target identity errors but not target position errors. The finding that flanker report errors were unchanged when training reduced crowding suggests that flanker reporting errors are more likely a result, not a cause, of crowding, in that the observers may be forced to report a more visible flanker when they fail to recognize the central target.

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43.415 **Music-reading training alleviates crowding with musical notation** Yetta Kwailing Wong[1](yetta.wong@gmail.com), Alan C.-N. Wong[2]; [1]City University of Hong Kong, [2]The Chinese University of Hong Kong

Crowding refers to the phenomenon in which recognition of a target object is disrupted by nearby distractors. Prior studies observed smaller crowding for perceptual experts in a number of object categories, such as faces (Louie et al., 2007), letters (Grainger, Tydgat & Issele, 2010) and musical notation (Wong & Gauthier, 2012). However, since experience was not manipulated in these studies, it was unclear whether these real-world experts happened to have better visuospatial resolution for the objects of expertise independent of perceptual experience. We tested whether crowding can be alleviated by music-reading training in the laboratory. Participants with intermediate music-reading ability completed eight hours of music-reading training within two weeks. In the match-to-sample training task, a target music sequence with four to five notes appeared briefly, followed by two sequences, one identical to the target and the other slightly different. Participants were required to identify the target sequence. The presentation duration of the sequence decreased if participants attained 90% accuracy in a block of 20 trials. After training, the average presentation duration was ten times shorter than that in session one. Crowding with musical notation was measured before and after training. For the baseline condition, participants judged whether a dot was on or off a line in the parafoveal region. For the crowded condition, four additional staff lines and two flanking dots were added around the target dot. After training, the Weber contrast threshold for 75% accuracy significantly decreased for the crowded condition but not for the baseline condition, and that for Landolt Cs stayed similar across training. Results show that crowding can be reduced with typical perceptual expertise training paradigms that refine high-level object representation, and it can be achieved without direct practice on the crowding task (e.g., Chung, 2007; Huckauf & Nazir, 2007; Sun et al., 2010).

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43.416 **Qualitative difference in categorical priming between conscious and unconscious processing of numbers: Evidence from visual crowding** Yih-Shiuan Lin[1](cblack13514@gmail.com), Su-Ling Yeh[1,2,3]; [1]Department of Psychology, National Taiwan University, Taipei, Taiwan, [2]Neurobiology and Cognitive Neuroscience Center, National Taiwan University, Taipei, Taiwan, [3]Graduate Institute of Brain and Mind Sciences, National Taiwan University, Taipei, Taiwan

The issue whether conscious and unconscious processes are quantitatively or qualitatively different is still hotly debated. We investigated numbers with or without visual crowding—a deleterious perceptual effect of cluttered peripheral stimuli—to examine the influence of crowded or isolated prime on the following target. Eight numbers, belong to either smaller category (1-4) or larger category (6-9), were used as prime and target in a magnitude-comparison task. We manipulated the relationship between prime and target (consistent or inconsistent in magnitude category). Participants were asked to indicate whether the target was larger or smaller than 5. Results showed positive magnitude priming in the crowded condition; response was faster when the prime and target belong to the same magnitude category. In contrast, negative priming (NP)—response was slower for magnitude-consistent prime-target pairs—was found in the isolated condition. This suggests that without awareness, the magnitude of the prime can still be processed to facilitate the response toward the following target of the same magnitude category. With full awareness, response corresponding to the magnitude of the prime is inhibited (since participants were not supposed to respond to it) and interferes with the response toward the target if both numbers belong to the same magnitude category. A flipped-over categorical priming effect is first discovered in numerical stimuli, supporting the hypothesis of qualitative difference between numbers processed consciously and unconsciously.

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43.417 **A new font to reduce crowding** Jean-Baptiste Bernard[1](jean-baptiste.bernard@univ-amu.fr), Carlos Aguilar[1,2], Eric Castet[1]; [1]Laboratoire de Psychologie Cognitive, CNRS, Marseille, [2]Essilor International

Crowding refers to the deleterious effect of surrounding items on object recognition. It affects the recognition of groups of letters and is presumably an important factor limiting reading performance. In this study, we investigated the possibility of designing a new font to reduce the effect of crowding on letter recognition. The new font (named the ABC font) was designed to decrease the physical similarities of letters frequently confused during crowding. The 26 ABC letters derive from lowercase and uppercase symbols of classical fonts. They are low-complexity letters with special attributes including oblique or curved strokes that increase their specificity. We measured letter recognition performance for the ABC and Courier fonts in four subjects. The task consisted of the recognition of three crowded letters of the same font, horizontally aligned and briefly presented at 6° eccentricity in the lower visual field (1,000 trigrams per font and per subject, duration: 100-200 ms depending on subjects' performance). Center-to-center spacing was the same for both fonts (Courier standard spacing) as well as the letter stroke-width and x-height which was set to the critical print size (CPS, range: 1.09°-1.18°) for each subject (values larger than the CPS do not increase reading speed). For each subject, crowded letter recognition performance was much higher for ABC than Courier font: Errors decreased by 43.91% on average (range: 37-50%), from 0.78 to 0.43 letter errors per trigram. Frequently confused pairs (>5% confusion errors) were reduced from 25 to 9 pairs on average with ABC compared to Courier. Letter mislocation rates were similar for both fonts (0.16 mislocation errors per trial for Courier and 0.13 mislocation errors for ABC on average). These results suggest that crowded letter recognition performance can be increased by reducing physical similarities between letters.

43.418 **Crowding predicts reading abilities** Oren Yehezkel[1,2](yehez@post.tau.ac.il), Anna Sterkin[2,3], Maria Lev[2,3], Uri Polat[2,3]; [1]School of Optometry and Helen Wills Neuroscience Institute, UC Berkeley, Berkeley, CA, USA, [2]GlassesOff Inc., New York, USA, [3]Faculty of Medicine, Goldschleger Eye Research Inst, Sheba Medical Center, Tel Aviv University, Israel

Background: Previously we have shown high correlation between visual acuity (VA) measured using the GlassesOff application for near vision evaluation (eVA) and VA measured using a standard ETDRS chart. Moreover, we have shown that eVA can predict the functional reading acuity along with the minimal font size one can recognize under good illumination conditions. Methods: Near VA was measured in over 100 subjects with age ranging between 20-69 years performed eVA from 40 cm, using GlassesOff application on iOS-based mobile devices (iPhone, iPad, iPod). The stimuli were matrices composed of 25 letters "E" (5×5), each with a randomly chosen orientation out of 4 possibilities (left, right, up or down). Two variations of inter-letter spacing within matrices were used (0.4 and 1 letter). The task was to report the orientation of the central letter. The evaluation was performed using a staircase measuring the minimal detectable letter size. For each staircase, the duration of target presentation (30, 60, 120, 240 msec). Reading acuity was measured using the standard MNREAD chart. We aimed to evaluate whether age-related changes in crowding can explain the age-related reduction in reading abilities and whether eVA can reliably predict reading abilities. Results: Firstly, consistent with an earlier study (Baron & Westheimer, 1973), eVA decreases for shorter presentation durations. Moreover, crowding measured using eVA is correlated with age, with higher correlation for shorter presentation durations. Furthermore, crowding is highly correlated with the reading acuity, again with higher correlation for shorter presentation durations. Conclusions: The observed age-dependent increase in crowding and the consequent decrease in functional reading acuity indicate that remote eVA can accurately predict reading abilities. Moreover, our results suggest a neuronal mechanism for earlier reported reduction in crowding following training with our perceptual learning method, resulting in improved reading acuity in presbyopic and young subjects.

Acknowledgement: GlassesOff Inc.

43.419 **Foveal letter crowding: Is it due to contour interaction or gaze instability?** Vineela Varikuti[1](varikutivineela@gmail.com), John Siderov[1], Ebi Osuobeni[1]; [1]Vision and Hearing Sciences, Anglia Ruskin University, Cambridge, U.K.

Aim: Foveal crowding has been suggested to comprise elements of contour interaction, gaze instability and attention (Flom, 1991). The aim of this study was to investigate if the decreased visual thresholds with crowded vision charts are due to contour interaction or gaze instability by comparing visual acuity for repeat and complex (non-repeat) letter chart designs

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with equal inter-letter separations. Methods: Visual acuity for 3 normal (NE) and 4 amblyopic observers (NAE and AE) was determined using a method of constant stimuli for high contrast Sheridan Gardiner (SG) letters (black on white) in repeat letter chart format (SGR). Similar measurements were made for SG letters arranged in a complex letter format (SGC) similar to the Flom 'S' Chart. Inter-letter separations for both the charts ranged from abutting, 0.2, 0.4, 0.6, 1.0 letter width separations. For comparison, single letter, unflanked acuity was also measured. For some observers, inter-letter separation for the SGC chart was extended beyond 1.0 letter widths until acuity equaled SGR acuity at 1.0 letter width. Results: Isolated SG letter thresholds equaled SGR thresholds at 1.0 letter width and SGC thresholds for ≥ 1.0 letter width separations. SGC thresholds were significantly higher than the SGR thresholds indicating a crowding effect (ANOVA, $P<0.05$). However, the difference in thresholds between the two charts remained constant between the abutting and 1.0 letter separation conditions and averaged 0.08, 0.13 and 0.23 LogMAR for the NE's, NAE's and AE's respectively. Conclusions: The constant difference between repeat and complex (non-repeat) letter chart acuity for close inter-letter separations suggests that imprecise or inaccurate fixation contributes to foveal crowding. The difference between the two chart formats was more exaggerated for amblyopic eyes. This result confirms earlier reports showing the importance of relative gaze in assessing visual acuity and evaluating foveal crowding in both normal and amblyopic vision.

43.420 **Effects of stimulus duration on foveal crowding using visual acuity letters.** Sarah J Waugh[1](sarah.waugh@anglia.ac.uk), Monika A Formankiewicz[1], M Izzuddin Hairol[1,2]; [1]Anglia Vision Research, Department of Vision and Hearing Sciences, Anglia Ruskin University, Cambridge, U.K., [2]Program Optometri & Sains Penglihatan, Universiti Kebangsaan Malaysia, Kuala Lumpur, Malaysia

Previously we reported fixed foveal zones of contour interaction/crowding of up to 4 arcmin for luminance-modulated Cs, 12 arcmin for contrast-modulated Cs and 4 arcmin for luminance letters (Waugh et al, VSS 2012; Hairol et al, 2013; Siderov et al, 2013). These zones remain constant in extent for different target contrasts and retinal illuminances, despite a wide range of letter sizes used to generate constant isolated-letter performance. In this study, we investigate the effects of stimulus exposure duration on foveal crowding zones for letter acuity. In the periphery, crowding zones increase in size for briefly presented stimuli (Tripathy et al, 2002 and VSS2013). High contrast letters (H O T V) were presented at sizes that generated 80-90% performance level when isolated. Stimulus duration (800, 400, 200, 100, 50 and 25ms) and flanker type (box, bars and letters L A U C) were varied systematically in blocks. Within an experimental run, one of 10 flanker separations (0-10 arcmin), including the isolated condition, was randomly presented using a Method of Constant Stimuli, and performance monitored. The measured crowding function is dependent on flanker type ($p<0.05$) and stimulus duration ($p<0.05$), with the box showing weaker overall crowding. On average, at 25ms, the crowding function is shallower and broader than at longer durations. The spatial extent for which performance for a crowded letter is statistically different from an isolated letter, changes from 3-4 arcmin for longer durations (200-800ms), to 8 arcmin at the shortest duration of 25ms; with fitted (Gaussian) extents of 2.5 to 6 arcmin. Weaker crowding by the box may reflect a fast grouping process. Temporal changes in crowding at the fovea are similar to those reported in the periphery, indicating that contributions at short durations to the crowding function engage larger underlying mechanisms.

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43.421 **Foveal crowding exists for short presentation times and reduces after training** Maria Lev[1](mariale2@post.tau.ac.il), Oren Yehezkel[2,3], Anna Sterkin[1,3], Uri Polat[1,3]; [1]Faculty of Medicine, Goldschleger Eye Research Institute, Sheba Medical Center, Tel Hashomer, Tel Aviv University, Israel, [2]School of Optometry, University of California, Berkeley, CA, USA, [3]Glassesoff, New-York, NY, USA

Visual crowding, the inability to recognize objects in clutter, sets a fundamental limit on visual perception and object recognition. It is assumed that, in the normal fovea, crowding does not exist or it only occurs over very small distances. Recently we showed that spatial and temporal crowding are correlated in the amblyopic fovea and normal periphery, suggesting a tradeoff between spatial and temporal processing of crowding. We showed (VSS 2013) that limiting stimulus availability using backward masking results in increased crowding and slower reaction time. Here we tested the crowding effect without backward masking. We used a method originally termed "contour interactions" to measure the surround effect on recognition of a single E letter size and target-flanker spacing of either 1 or 0.4 letter size, which is assumed to be at the border of the critical window of crowding in terms of letter spacing. We measured the crowding effect as a function of presentation time (30-240 msec). We also explored how a training consisting of detecting Gabor stimuli under spatial and temporal masking affects crowding (Polat et al., 2012). The training was carried out on iDevices at a distance of 40 cm (using the GlassesOff application). We found that robust crowding exists in the fovea: participants overcome crowding for long presentation times of 240 msec but exhibit crowding for short presentation times of 30 and 60 msec. After training, the crowding effect is reduced significantly, even for a presentation time of 30 msec. Thus, normal processing of foveal information is efficient for overcoming crowding with presentation times longer than 240 msec. Training improves processing speed, an effect that enables more efficient foveal processing to overcome crowding even for shorter presentation times. Our results suggest that temporal processing is a very important factor in processing of the crowding effect.

43.422 **Crowding is similar for eye movements and manual responses** Funda Yildirim[1,2](fundayildirim@gmail.com), Frans W. Cornelissen[1,2]; [1]Experimental Opthalmology, University Medical Center Groningen, [2]Behavioral and Cognitive Neurosciences, Graduate School of Medical Sciences

Crowding is an ambiguity in the peripheral vision that occurs when a target is surrounded by other –similar- objects. Crowding is typically studied using manual responses. Peripheral vision, however, is used for planning eye-movements. This begs the question whether crowding as measured when participants respond with their eyes is different from when they respond by hand, while fixating. On top of that, recent reports suggest either reduced or increased crowding around saccade initiation. If such effects would significantly influence crowding this would be important to know. In this experiment, a reference and a target (an oriented target Gabor) were positioned either left or right of a central fixation point. To measure the perceived position of the target, observers indicated the position of the target (the right most tilted one). Conditions involved presenting isolated reference and target, as well as conditions in which both were surrounded by identical flankers. Target selection was indicated by the participant either via button responses or via eye movements. Results revealed that responding by eye or by hand did not affect target recognition performance. Response times were also similar. Hence, we conclude that for all practical purposes, crowding can be considered identical for either type of response.

Color and light: Adaptation and constancy

Monday, May 19, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

43.423 **Interocular lateral interaction subserves dichoptic positive color aftereffects** Chien-Chung Chen[1,2](c3chen@ntu.edu.tw), Huan-Tin Chen[1], Takao Sato[3]; [1]Department of Psycholopgy, National Taiwan University, [2]Center for Neurobiology and Cognitive Science, National Taiwan University, [3]Department of Psycholopgy, University of Tokyo

After adapting to monocularly presented color stimulus, an observer may experience an aftereffect with the same hue as the adaptor (positive aftereffect) if the contour of the adaptor was presented to the unadapted eye (Sato & Nakajima, 2010, ECVP). We investigated the mechanisms underlying this positive aftereffect. The adaptor was a colored square (2ox2o). The adaptor hue was either red (L-M), green (M-L), blue (+S) or yellow (-S). In each trial an adaptor was presented to one eye for 1s, followed by a test phase, in which the observer was to match the hue and contrast of a test patch with the aftereffect. There were three test conditions: (1) the monocular condition: a square frame surrounding the adapted area was presented to the adapted eye; (2) the dichoptic condition: the test frame was presented to the unadapted eye; and (3) the no-frame condition. Compared with the no frame condition, the presence of a frame increased the aftereffect by 22-110% across different colors. The aftereffect in the dichoptic condition had the same hue as the adaptor but opposite hue in the monocular condition. Replacing the square with a cross in the test phase, the positive aftereffect occurred only near the bars and shaped like a diamond, suggesting such effect is induced by the edges. Showing either adaptor or test frame binocularly dramatically reduced the aftereffect. The observer perceived a negative aftereffect in the dichoptic condition when a luminance mask was presented to the unadapted eye and an enhanced positive aftereffect if the mask was presented to the adapted eye, suggesting that positive and negative aftereffects coexist in different eyes. Since the context was added only in the test phase, the positive aftereffects cannot be explained by simultaneous contrast. Instead, an interocular suppressive lateral interaction was needed to explain our result.

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43.424 Flicker adaptation desensitizes the magnocellular but not the parvocellular pathway

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Purpose: Previous studies reported that flicker adaptation reduces temporal contrast sensitivity (Robinson & de Sa, 2012). To assess whether flicker adaptation occurs in the magnocellular (MC-) or parvocellular (PC-) pathway, or in both, contrast detection and discrimination thresholds were measured following adaptation to a flickering light, using the steady- and pulsed-pedestal paradigms that separately measure contrast sensitivity of the inferred MC- and PC- pathways (reviewed by Pokorny, 2011). Methods: The stimulus was a pedestal array with four squares, each subtending either 1°x1° or 0.57°x0.57°. The array was presented within a 37°x27° steady surround (12 cd/m2). In the steady-pedestal paradigm, observers adapted to either a steadily presented or square-wave modulated pedestal (2 or 10 Hz, 50% contrast) at various mean pedestal luminances. After adaptation, the pedestal at mean adapting luminance was present briefly (26.6 ms), with a test square having incremental or decremental luminance. In the pulsed-pedestal paradigm, observers adapted to a steadily presented or square-wave modulated pedestal with a fixed mean luminance at 12 cd/m2. The pedestal with an incremental or decremental luminance from the mean adapting luminance was then briefly pulsed (26.6 ms), with a test square having a larger luminance change. The task was to identify the test square in a four-alternative-force-choice staircase procedure estimating contrast thresholds. Results: For both stimulus sizes, adaptation to a flickering pedestal significantly reduced the sensitivity of the inferred MC-pathway but did not alter sensitivity of the inferred PC-pathway. This effect was stronger for 10 Hz than for 2 Hz (about 0.2 and 0.1 log unit desensitization respectively, p<0.001). Notably, contrast detection threshold was not determined by the PC-pathway even after the MC-pathway was desensitized. Conclusion: The MC-pathway can be desensitized independently from the PC-pathway, providing a powerful tool for independent examination of visual processing in these two pathways.

43.425 The Twinkle Aftereffect Is Modulated by Attention and Awareness

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Following adaptation to a uniform patch surrounded by dynamic random noises, observers often can perceive some twinkle noises in the region of the uniform patch when they view a blank field. This is called the induced twinkle aftereffect (TwAE). Previous studies suggest a possibly early neural site for the TwAE. For example, there is no interocular transfer of the TwAE, implying that the mechanism responsible for the TwAE is not beyond V1. In the current study, we investigated the role of attention during the formation of the TwAE. Results show that directing attention away to an irrelevant RSVP task significantly reduced the duration of the TwAE. In other words, the TwAE is modulated by attention. We further investigated the role of awareness in the TwAE, preliminary observation based on manipulating the flicker frequency suggests that the TwAE is dependent on awareness of the flickering surround. Rendering the surrounding dynamic noise invisible (sometimes intermittently) through continuous interocular suppression also significantly reduced the TwAE duration, compared to monocular viewing, further supporting the important role of awareness in generating the TwAE. Together, results from this study suggest that the twinkle aftereffect may be a multi-stage phenomenon and mechanisms beyond V1 may also contribute to its formation.

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43.426 Colour appearance and age-related adaptation mechanisms

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While the peripheral visual system changes with age, the subjective experience of colour is to a large extent invariant across the life span. Here we investigate whether these age-related mechanisms that mediate hue constancy operate in a similar manner under different ambient illumination conditions (dark adaptation; adaptation to D65 or CWF). To assess colour appearance, a hue selection task was employed with a large sample of colour-normal observers (n=185). Our main result is that significant age-related changes in colour appearance are only found for unique green settings under daylight viewing conditions which is consistent with the idea that the yellow-blue mechanism is most affected by an increase in age due to selective attenuation of short-wavelength light. Implications for age-related adaptation mechanisms will be discussed.

43.427 The effects of delay and chromatic noise on hue bias and precision

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Background. A short delay between the presentation of a reference and a test stimulus in a two-alternative hue estimation task biases estimates toward the average stimulus value (Olkkonen & Allred, VSS 2013). Here we characterize the conditions for the bias by 1) manipulating the delay between reference and test ("internal noise") and 2) manipulating the chromatic variability in the reference ("external noise"). Methods. Two-alternative hue judgments were collected in two experiments for stimuli varying on the blue-yellow continuum. In Experiment 1, observers made judgments between two patches displayed on left/right of fixation across delays of 0.4, 2, and 4 seconds, interleaved. In Experiment 2, a new group of observers made judgments across a fixed 2 second delay with three interleaved levels of chromatic noise in the reference stimulus. In both experiments, the reference was always presented first; three interleaved references were employed. Test hue was varied to measure psychometric functions (PMF), from which bias and precision were estimated. Bias was defined as the difference between each point of subjective equality (PSE) and veridical reference hue; precision was the reciprocal of discrimination threshold (75th -50th percentile of the PMF). Results. Experiment 1. Hue estimates across the shortest delay were not biased, but a central tendency bias emerged with the longer delays. Thresholds increased slightly overall with delay, but there was no significant relationship to bias. Experiment 2. Hue bias increased monotonically with increasing chromatic noise in the reference. Thresholds increased slightly overall, and were moderately correlated with bias magnitude across observers and noise level (r=0.45, p<0.001). Conclusion. Biased hue percepts can be elicited both with an internal (delay) and an external (chromatic variability) noise manipulation. The difference in relationship between bias and thresholds for the two manipulations suggests that different mechanisms might underlie hue appearance bias with external vs. internal noise.

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43.428 Colour Constancy in Immersive Viewing

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Colour constancy measurements typically involve the participant viewing a limited-field scene (e.g., on a display screen) from an external vantage point (e.g., through a porthole) and comparing surface colours across a small number of distinct illuminations. Here we report colour constancy measurements from an immersive viewing setup in which scene appearance comparisons are made between multiple distinct illuminations. The setup consists of an enclosed room (approx. 2.5m x 2.5m x 2.5m) with all interior surfaces painted white, illuminated solely by multiple-channel LED light sources whose outputs are spectrally tuneable in real-time. Participants (n=6) sat inside the room on a black bench, facing a Mondrian-paper-lined three-sided open box positioned on a black pedestal approx. 1.5m distant, and gave responses via a black joystick. There were no other room contents. A 2-down, 1-up staircase protocol determined just-discriminable global illumination changes. Poorer discrimination of illumination change implies better colour constancy. On each trial, the reference illumination (D67) was shown for 2000ms followed by two test illuminations of 500ms each; each illumination change was preceded by a 400ms dark period. One test illumination was identical to the reference; the chromaticity of the other varied parametrically in uniform colour space from the reference target in one of four chromatic directions, blue or yellow (on the daylight locus), or red or green (on an orthogonal locus). All illuminations were the smoothest-possible metamers for the requested chromaticity. Illumination discrimination thresholds, calculated by averaging final staircase reversals, were lower on the orthogonal red-green locus than the daylight locus (p <0.06), and significantly higher for "bluer" illumination changes than "greener" directions (ΔEuv = 17.2 vs 6.2; p <0.03). Global illumina-

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tion change discrimination thus provides a robust method for assessing colour constancy in immersive viewing, and the results support the notion that constancy mechanisms are biased towards daylight illuminations.
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43.429 Effects of Illuminant chromaticity on color constancy David Weiß[1](david.weiss@psychol.uni-giessen.de), Karl Gegenfurtner[1]; [1]Department of Psychology, Justus-Liebig-University Giessen

Past research on color constancy has mainly focused on surfaces illuminated by a restricted set of illuminants. Since other visual functions related to color, such as color discrimination, exhibit systematic variations with hue, we wanted to investigate whether there are systematic differences in the degree of color constancy between illuminants of varying hues. We varied chromaticity and saturation of the illuminant in rendered two- and three-dimensional scenes displayed on a LCD screen extending a visual angle of 58.9° x 38.9°. The scenes depicted different versions of an illusion introduced by Lotto & Purves (2004). Ten naïve observers performed achromatic matches on scenes illuminated by illuminants of 20 different chromaticities and two saturation levels. The surface reflectances were chosen from the axes of DKL-Color-space, rotated in steps of 18° azimuth in accordance with the illuminants. Each Illuminant was chosen so that it exactly canceled the chromaticity of one of the surface colors used. Observers had to adjust a central patch in the scene until it appeared achromatic to them. Color constancy was defined as the magnitude of the correction observers used to adjust a gray, relative to the shift of the neutral patch under that illuminant. We observed levels of color constancy between 25% and 75% for different observers and conditions. There were only small differences between 2D- and 3D scenes and for the two different saturation levels. There was a trend towards higher constancy for illuminants varying in color directions close to the daylight locus. Overall, color constancy seems to be fairly stable across different illuminant directions. Lotto RB, Purves D (2004) Perceiving Colour. Review of Progress in Coloration 34: 12-25.

43.430 Color constancy and palette complexity in real scenes
Patrice McCarthy[1](pfm54@camden.rutgers.edu), Maria Olkkonen[2], Sarah R Allred[1]; [1]Psychology Department, Rutgers -- The State University of New Jersey, [2]Center for Cognitive Neuroscience, University of Pennsylvania

Background: Scene complexity often improves color constancy, yet little research has investigated whether the complexity of the matching palette improves color constancy. Typically, matching stimuli are flat. Here we investigated whether color matches change when a 3D matching palette is used. Method: Observers viewed two adjacent, separately illuminated 4′ x 4′ x 4′ booths in which 3″ study cubes were placed. Matching palettes were mounted on covered circular rotating trays. Only one matching stimulus was visible at a time. Observers rotated the trays and judged whether each successive matching stimulus was painted with the same paint as the study cube. This allowed within-observer characterization of color precision. We used 8 study cubes and 128 matching paints that spanned the color space near each study cube. Matching stimuli were either 1″ flat squares or 1″ cubes. Matching palettes were either viewed under the same (baseline condition) or different (constancy condition) illumination as the study cubes. This was a repeated measures design. Results and Conclusion: In the baseline condition, cubes and flats elicited similar average matches and similar precision. In the constancy condition, average color matching error varied widely between study cubes. Errors were slightly higher with the cube palette than the flat palette. Between observers variability in average color matches was higher in the constancy than the baseline condition for both flat and cube stimuli. However, within observers, precision of color matches was similar between conditions. Thus, the higher between-observers variability in the constancy condition is likely due to individual differences in color constancy, rather than a decrease of precision in the representation of color within individuals. Conclusion: Overall, color matches are largely similar when made with both 2D and 3D palettes.
Acknowledgement: NSF BCS 0954749

43.431 Is color constancy influenced by the glossiness of color paper? Yoko Mizokami[1](mizokami@faculty.chiba-u.jp), Asuka Akahori[2], Hirohisa Yaguchi[1]; [1]Graduate School of Advanced Integration Science, Chiba University, [2]Department of Engineering, Chiba University

It has been suggested that specular component would contribute to color constancy since it reflects the color of illuminant. It was also reported that specular highlight improved color constancy in CG images. However, it is not clear how specular component contributes to color constancy of real objects under natural environments, which consist of a variety of materials and clues to illumination. In this study, we examine whether the specular reflection of a surface influences to color constancy by comparing papers with the different levels of glossiness. We built a booth arranged like a normal room illuminated by lamps with correlated color temperature 5000K or 2700K. Test samples were three-dimensional wavy surfaces covered with a gloss, a semi-gloss and a matt paper, respectively. We tested five color samples: 5YR 6/6□5P 6/6□5BG 6/6□5GY 6/6 and N6 in Munsell notation. Observers evaluated the color appearance of test samples using an elementary color naming method. Two viewing conditions were tested: a natural viewing condition and a limited-view condition in which observers only viewed a test sample through a black viewing box. As a result, the color appearance of test samples under two illuminations showed small differences in the natural viewing condition, meaning good color constancy. However, they did not show any systematic differences between the glossiness of paper, implying little contribution of specular component compared to other information in the surrounding. In the limited-view condition, the results still showed color constancy in some degree, suggesting the three-dimensional shape contributed to color constancy even though there was no information in the surrounding. We, however, did not find any differences in the glossiness of paper even in this condition. Our results suggest that the specular reflection of color paper has little effect on color constancy in a real environment.
Acknowledgement: KAKENHI 23135506

43.432 Color constancy in a natural task is high Ana Radonjić[1](radonjic@sas.upenn.edu), Nicolas P. Cottaris[1], David H. Brainard[1]; [1]Department of Psychology, University of Pennsylvania

Color constancy is often studied using adjustment procedures. In real life, however, we rarely adjust object colors. Rather, we use color to identify and choose objects. We studied constancy using a novel paradigm, adapted from the blocks-copying task of Ballard et al (2005). In our experiment, subjects were asked to complete a fairly natural task that required them to judge object color across an illumination change. At the beginning of each trial the subject saw three rendered scenes —the target, the source and the test— presented on a computer display. The target scene contained four colored blocks of different simulated reflectance. Their arrangement varied randomly on each trial. The source scene contained eight blocks: one pair of potential matches for each target block. The degree of similarity of each potential match to the target varied across trials. The test scene contained four identical dark gray blocks. The subjects' task was to replace the gray blocks with blocks chosen from the source, so as to recreate the arrangement in the target scene as closely as possible. In the illuminant-constant condition, all three scenes were rendered under the same illumination (D65). In the illuminant-changed condition, the simulated illuminations of the source and test were changed to 12000°K. Based on the subjects' choices, we inferred their perceptual matches for each target block in each condition via a variant of the maximum likelihood difference scaling method. Two main findings were consistent across our four subjects: (1) When the illumination was constant the distance between the target block and its choice-based match was small (2.2 - 3.9 ΔE), supporting the validity of our method. (2) When the illumination changed, the choice-based matches indicated good constancy (constancy indices 0.7 - 0.8). Our results show that color constancy is high when probed using a natural task.
Acknowledgement: NIH: RO1 EY10016, P30 EY001583

43.433 Light field interpolation across an insulating white border
Minjung Kim[1](mkim85@gmail.com), Kelly Ng[1], Laurence Maloney[1]; [1]New York University

The light field in a scene describes the light flow through each point in space from every direction. In previous work, we found that the visual system interpolates information about the light field across empty regions to an isolated test patch (Kim, Schüür & Maloney, 2013). Here, we examined whether we could disrupt the interpolation process by surrounding flankers with a uniform white border (by analogy with previous work in lightness perception; Gilchrist et al., 1999). Participants viewed a target (diamond) situated between two flankers (two large, white blobs) above and below the target for 750ms. The flankers were lit by a yellow proximal and a blue collimated light source. The task was to indicate whether the target needed more yellow or more blue light in order to appear neutral (white). The flankers appeared without borders in one condition (control) while, in two other conditions they were surrounded by borders. In one condition, the borders were lit as the flankers while in the other condition, the borders were not shaded. Neither the shaded nor the unshaded borders disrupted light field interpolation in four out of six observers. For the remaining two, we found failure of interpolation in all three conditions. A white border may not be sufficient to disrupt light field interpolation; light field interpolation is remarkably robust.
Acknowledgement: NSF 1059166

Perceptual organization: Grouping

Monday, May 19, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

43.434 **Neural correlates of spatio-temporal grouping in bistable apparent motion perception** Lu Shen[1](lu.shen2013@gmail.com), Lihan Chen[2], Qi Chen[1]; [1]Center for Studies of Psychological Application and School of Psychology, South China Normal University, Guangzhou 510631, China, [2]Department of Psychology, Peking University, 100871 Beijing, China

Upon viewing dynamic ambiguous visual stimuli, observers often experience spontaneous transitions between two competing percepts although the physical stimulation remains unchanged. This phenomenon is termed as "bistable perception", of which the perceptual groupings in space and time need to be implemented jointly. The Ternus display as one of the typical ambiguous apparent motion, depending on the interstimulus interval (ISI) between each frame of the motion sequence, can elicit two different percepts: explicit element motion (EM) percept (with shorter ISI, i.e., 50ms) or group motion (GM) percept (with longer ISI, i.e., 230ms) (i.e., the two filler conditions). More importantly, when the ISI reaches certain threshold (as measured by psychophysical method for each individual), the two percepts can be alternatively induced with equal possibilities with the bottom-up stimuli being constant (i.e., the bistable condition). By adopting fMRI in the present study, we aimed to investigate the neural mechanisms underlying the bistable apparent motion perception. As compared to the explicit EM percept (ISI=50 ms), the explicit GM percept (ISI=230 ms) significantly activated the bilateral middle occipital gyrus extending to bilateral lateral occipital cortex (LOC), suggesting that the explicit GM percept implicated the perceptual grouping process in the ventral visual areas. In the bistable condition, when the EM percept won the bistable percept competition, the left inferior parietal cortex showed not only increased neural activity, but also enhanced functional connectivity with premotor cortex, indicating the functional role of the dorsal parieto-premotor stream in subserving temporal grouping. In contrast, when the GM percept won the competition, the default-mode-network in medial prefrontal cortex (MPFC) showed reduced deactivation, indicating the functional role of MPFC in spatial grouping, rather than temporal grouping. Taken together, our results, for the first time, showed how parieto-premotor pathway and MPFC determine the outcome of bistable apparent motion.

43.435 **An early electrophysiological response associated with illusory contour processing is reduced by cognitive load** Ryuji Takeya[1,2](takeryu200@gmail.com), Tetsuko Kasai[3]; [1]Graduate School of Education, Hokkaido university, [2]Research Fellow of the Japan Society for the Promotion of Science, [3]Faculty of Education, Hokkaido university

It is known that figures with illusory contours (IC) evoke a specific electrophysiological response in comparison with control figures at around 110-200 ms after stimulus onset. Because previous studies have shown that this IC effect is equally observed regardless of ongoing perceptual tasks, it may reflect automatic perceptual processing of IC in visual cortical areas. However, it is still not clear whether the IC effect can be affected by cognitive task load, which is another possible factor to modulate visual processing. The present study examined this issue by using event-related potential (ERP). Method: IC and control figures were formed by using the arrangement of 4 packmen. The IC, control, and digit stimuli (1-9) were randomly presented (presentation ratio was 2:2:1). ERPs were recorded from 17 participants who were viewing the stimuli and simultaneously counting the number of digits (low-load task) or subtracting current digits from 400 (high-load task). Results: ERPs in response to the IC figure was observed to be more negative than those in response to the controls at 110-160 ms post-stimulus over the right occipital-temporal electrode sites. Importantly, this effect was found only for the low-load condition. ERPs in an earlier latency range (80-110 ms) did not differ by tasks or figures. Discussion: We identified an IC effect for the low-load condition, which was similar to that in the previous studies, while this effect was completely absent for the high-load condition. There was no difference in the earlier P1 latency, which suggests that cognitive load associated with calculations specifically affected IC processing without mediating lower-level visual processing or spatial attention. The present study shows that IC processing is not completely automatic and shares some processing resources with cognitive operations.

43.436 **Grouping-based attention influences surround suppression in human primary visual cortex** Anastasia Flevaris[1](ani.flevaris@gmail.com), Scott Murray[1]; [1]Department of Psychology, University of Washington

Surround suppression is a form of contextual modulation in V1 in which the response to a stimulus inside the receptive field of a neuron is reduced when it is surrounded by stimuli just outside of the receptive field. The suppression is greatest when the surrounding stimuli share the same low-level features such as orientation and spatial frequency. In contrast, previous studies of perceptual grouping have shown that attending to one element in a group automatically spreads to other members of the group, thereby increasing the neural response to similar features. A key difference between findings of grouping-based suppression versus enhancement is directed attention. Investigations of surround suppression have predominately examined suppression to unattended elements, and the few studies investigating attentional influences on surround suppression have used displays in which grouping could not be explicitly examined. Here, we asked if both effects could be seen in the same paradigm by using three-element displays that could be perceptually grouped and manipulating the direction of attention. The displays consisted of a center oriented Gabor and two flanking Gabors positioned above and below the center. The center and surrounding Gabors either had the same or orthogonal orientation, and attention was directed either to the center element or to the upper (surrounding) element. Using fMRI, we measured the V1 response to the center element when it had the same orientation as the surrounding flankers versus when the orientations differed. When attention was directed to the center element itself, we found evidence of surround suppression; the V1 response to the center element was reduced when the surrounding orientations were the same relative to when they were different. In contrast, when attention was directed to the upper element, grouping-based attentional spreading reversed this effect, demonstrating a high-level influence of grouping-based attention on surround suppression in V1.

43.437 **Stimulus Features Contributing to Perceptual Organization of Complex Scenes** Beliz Hazan[1](beliz.hazan@gmail.com), Daniel D. Kurylo[1], Zeynel Baran[2], Xuan Zhao[3]; [1]Psychology Program, Graduate Center of CUNY, [2]Experimental Psychology Department, Hacettepe University, Turkey, [3]Electrical and Computer Engineering Department, Polytechnic Institute of New York University

For complex, natural scenes, which contain multiple sources of visual information, high-order visual cognition relies on accurate organization of stimulus components. Perceptual organization is based upon stimulus metrics as well as top-down factors, including contextual cues and familiarity. Gestalt principles, such as common luminance, color, and surface texture, or good continuation of contrast borders, allow segregation and integration of elements across broad areas and occluded regions. It was hypothesized that component visual features, specifically color, high- and low-spatial frequencies, and surface information, each contribute significantly to perceptual organization of natural scenes. To test this, 34 participants viewed 60 briefly presented scenes, selected from a standardized data set, and categorized scenes as either forest, mountain, ocean coast, houses, highway, or city skyline. Each image was presented as a series of 19 trials, beginning with a highly occluded image, and progressively providing a greater percentage of the image. Performance was indexed as the occlusion level at which correct categorization stabilized. Five image filter conditions were examined: (1) original (unfiltered), (2) color filter (grayscale), (3) high-pass and (4) low-pass spatial frequency filter, and (5) surface field filter. In addition, images were presented either upright (familiar) or inverted (unfamiliar) for each filter condition. Results indicated that for upright as well as inverted images, high-pass, low-pass, and surface field filters significantly reduced performance (ANOVA, $p < .05$), whereas color filter has a modest affect performance. Greatest impairment was found for the low-pass and surface field filter conditions. These results indicate that coarse information, which reduces detail, is less beneficial in perceiving scene organization. In addition, information from edges needs to contain sufficient detail to facilitate perceptual organization of complex scenes.

Acknowledgement: This research was partially funded by Doctoral Student Research Grant from the Graduate Center of CUNY

43.438 **The relation between acuity of the Approximate Number System and dorsal and ventral stream functions** Sara Giovagnoli[1](sara.giovagnoli@unibo.it), Mariagrazia Benassi[1], Kerstin Hellgren[2], Lea Forsman[3], Roberto Bolzani[1]; [1]Department of Psychology, University of Bologna, [2]Department of Clinical Neuroscience, The Karolinska Institute, Stockholm, [3]Department of Women's and Children's Health, The Karolinska Institute, Stockholm, Sweden

Children and adults can approximate numbers of items, compare these approximations, and perform approximate arithmetic operations via a non-symbolic, pre-linguistic system called the Approximate Number System (ANS). Studies using neuroimaging techniques demonstrated the role of the parietal cortex in decoding both non-symbolic and symbolic quantity. Although it has been proven that the parietal regions are involved also in visual processing such as coherence motion perception, little is known about the relationship between these visual processes and the ANS. The aim of this study is to investigate whether the acuity in the ANS is related to dorsal and/or ventral visual functions. A sample of sixty-five typical development children (age 6-10 years; 42 males and 23 females) took part in the experiment. ANS acuity was measured using a numerical discrimination task (Halberda et al., 2008) in which participants were briefly shown arrays of yellow and blue dots and had to identify the more numerous array; a motion coherence test and a form coherence test were applied to evaluate dorsal and ventral stream functions respectively. In the motion test participants were asked to detect the direction of moving dots, in the form test participants had to recognize a form created by spatially aligned dots. We found significant correlations between ANS acuity and motion perception ability ($p=0.014$) as well as form discrimination ability ($p=0.047$). More specifically, higher performance in the motion and form tests are related to higher ANS acuity. The effect size values show that the magnitude of the relationship with the ANS was higher for the motion (partial $\eta 2=0.09$) than for the form coherence test (partial $\eta 2=0.06$). These results demonstrate that both dorsal and ventral visual processing influence ANS acuity but that the association between ANS and dorsal stream processing is slightly stronger.

43.439 **The Perceptual Grouping Model in Contour Completion** Gal Nir[1](nga@post.bgu.ac.il), Ohad Ben-shahar[2]; [1]The Department of Brain and Cognitive Sciences , Ben Gurion University of the Negev, [2]The Department of Computer Science, Ben Gurion University of the Negev

Visual completion, the perceptual process of completing visual information missing due to occlusion, is a fundamental organizational process that facilitates much of higher level vision. The general problem of contour completion is typically divided into the grouping problem and the shape problem, where the latter deals with the reconstruction of the perceptually completed shape between given inducers while the former copes with the grouping of all inducers in the stimuli into pairs (or larger groups) between which shape is completed. While previous computational work has addressed mostly the shape problem, perceptual and psychophysical work has addressed both issues. Even so, perceptual studies of the grouping problem have been restricted to the conditions by under which a given pair of inducers is indeed grouped to induce a completed contour, rather than the studying the grouping process in multi-inducer scenarios. Here we investigate in issue in stimuli with two pairs of inducers, exploring psychophysically the stimuli features that lead to the selection of a specific grouping decision from the set of all possible groupings. We employ a dot localization paradigm (Guttman and Kellman, 2004) and report grouping results based on the independent parameters of the geometric and physical properties of the inducers, in particular their relative angle and their distance. The grouping model that emerges extends the popular relatability theory (Kellman and Shipley, 1991) and readily allows the future incorporation of top-down factors like familiarity, shape priors, and attention.

43.440 **Can a competition between grouping principles be resolved without attention?** Einat Rashal[1](einatrashal@gmail.com), Yaffa Yeshurun[1], Ruth Kimchi[1]; [1]Institution of Information Processing and Decision Making, Department of Psychology, University of Haifa

The goal of the present study was to examine whether attention is required for resolving the competition between two grouping principles operating on the same elements in the display. To this end, we used an inattention paradigm, in which the observer's attention was focused on a central task while irrelevant grouping displays were presented in the unattended background. The background displays were organized into two organizations, each of which was previously found to occur under inattention when presented alone: grouping into shapes (square/triangle) by element connectedness, and grouping into rows/columns by color similarity. On each trial, participants performed a demanding change-detection task on a small target matrix at fixation. Independently of any change in the target, the unattended grouping organizations in the background could change or stay the same, independently in each of the grouping organizations, creating congruency relations between the central target and the background organizations. Congruency effects were expected if the background organizations could be achieved under inattention. However, if the competition between grouping principles cannot be resolved without attention, congruency effects are not expected to emerge. We found that changes in the background organization by connectedness produced congruency effects upon the accuracy of the target-change judgments: target 'same' responses were more accurate when the background shape stayed the same than when it changed, and target 'different' responses were more accurate when the shape changed than when it stayed the same. However, no congruency effect was found for the organization by color similarity. When probed with surprise questions, participants could not report the organization on which the target appeared in the preceding display or whether the organization had changed on the preceding trial, confirming the condition of inattention. These results suggest that the competition between grouping principles can be resolved without attention.
Acknowledgement: Israeli Foundation Trustees (IFT)

43.441 **Contextual disambiguation of rotating Necker cubes** Marouane Ouhnana[1](marouane.ouhnana@mail.mcgill.ca), Frederick Kingdom[1]; [1]McGill Vision Research, Department of Ophthalmology, McGill University

Ambiguous figures perceptually alternate between different interpretations, and the particular interpretation is known to be affected by context. The aim of the study was to investigate the effect of an unambiguous rotating wire cube with various motion parameters on the perceived direction of an adjacent Necker cube continuously rotating at constant speed. The context figure parameters were rotation speed (same as, half, or twice the speed of the ambiguous figure) and rate of reversal (intervals between reversals 2s, 4s, and 8s). The two rotating figures were presented above and below fixation for 32s per trial. Observers indicated via key-press the direction of rotation of the ambiguous figure. Results show that the rate of ambiguous figure reversals was dependent on context, specifically reversal rates were correlated with those of the context figure. For some observers the correlation between reversal rates also depended on the similarity of speeds. These results suggest that changes in motion direction more than speed similarity binds ambiguous object motion to its unambiguous motion context.
Acknowledgement: Canadian Institute of Heath Research grant #MOP 123349 to F.K.

43.442 **Conjoint Effects of Spatial Proximity and Binocular Disparity in Perceptual Grouping.** Steven Scheid[1](sks6ev@virginia.edu), Sergei Gepshtein[2], Michael Kubovy[1]; [1]University of Virginia, [2]Salk Institute

The Gestalt psychologists insisted that the whole is other than the sum of its parts. This can be tested using conjoined grouping factors in multi-stable dot lattices where the factors compete or cooperate in producing a global perceptual organization. For example, conjoined factors of spatial proximity and similarity operate additively (Kubovy & van den Berg, 2008), but conjoined factors of spatial and temporal proximity do not (Gepshtein & Kubovy, 2007). Here we studied dot lattices in which we conjoined the factors of spatial proximity and stereoscopic depth by varying inter-dot distances and binocular disparity. The lattices were briefly presented in a mirror stereoscope and the observers reported the perceived orientations of dot groupings. We computed the log-odds of grouping in a given orientation based on the relative strengths of the two grouping factors. We found that binocular disparity strongly modulated effects of spatial proximity, but effects of binocular disparity were highly nonlinear. Increasing the depth separation between dots weakened their grouping for small binocular disparities. For large disparities, however, the trend was reversed: increasing depth separation between dots strengthened their grouping. The effect of binocular disparity was attenuated by surface cues (starry night textures; Zabulis & Backus, 2004) that implied a common surface for all elements of the lattice, indicating that grouping is modulated by the perception of whether the elements belong to the same surface.

43.443 **Grouping by similarity is serial, irrespective of spacing or group size** Dian Yu[1](dianyu2017@u.northwestern.edu), Derek Tam[2], Steven Franconeri[1]; [1]Department of Psychology, Weinberg College of Arts and Sciences, Northwestern University, [2]Department of Preventive Medicine, Feinberg School of Medicine, Northwestern University

Our visual system groups areas of the world that share common features. One potential mechanism for similarity grouping is global selection of the similar feature (red, horizontal, square, etc). Grouping a set of

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See page 3 for Abstract Numbering System

red objects might be the same as selectively enhancing areas of an image that contain red, and the same type of process might occur for shape or orientation grouping (e.g. enhancing regions of high curvature or horizontality). The exciting prediction from this account is that only a single group could be constructed at any given moment - the red or the green - but not both simultaneously. This prediction starkly contrasts with the intuition that similarity grouping is parallel. Past work using visual search tasks suggests that similarity grouping is indeed serial. Here we tested further implications of this mechanism: if similarity grouping is created through global feature-based attention, then grouping speed should not be influenced by (1) spacing among elements constructing groups, or (2) how many elements there are in each group (group size). Experiment 1 shows that searching is serial for an unmatched pair of colored squares among matched pairs and vice versa. Moreover, search rates do not differ for groups of widely spaced elements or tightly spaced elements (approximately 50ms/group). Experiment 2 tests whether the number of elements per group affects the time required to construct each group. Consistent with our prediction, searches for particular groups made of four objects were no slower than searches for two-object groups. Collectively, the current results suggest that grouping by similarity is serial, irrespective of spacing or group size. This supports the surprising account that similarity groups are constructed by selecting similar features in a serial manner.

Acknowledgement: NSF IIS-1162067

43.444 **What's the purpose of perceptual averaging?** Jennifer Corbett[1](jennifer.e.corbett@gmail.com), David Melcher[1]; [1]University of Trento Center for Mind/Brain Sciences

Introduction: Observers represent the average properties of sets even when they cannot identify individual elements (Ariely, 2001). Although it has been proposed that these representations complement limited capacity focused attention (e.g., Alvarez, 2011), there has yet been no empirical investigation of their functional role in visual perception. Indeed, the visual system could capitalize on statistical regularities inherent in the surrounding environment to create the illusion of stable and complete perception amidst constantly changing retinal imagery, despite its limited capacity to represent more than a handful of objects in detail. In support of this proposal, we present behavioral, eye tracking, Steady State Visual Evoked Potential (SSVEP), and patient data demonstrating that statistical stability facilitates visual search. Methods: We manipulated the statistical regularity of a visual scene over time while observers performed a search task. Specifically, we modulated the mean size of an array of Gabor patches while observers searched for a left or right tilted target among horizontal distractors. In 'stable' blocks, the mean size of the Gabor patches was constant over successive displays, whereas in 'unstable' blocks, it changed from trial-to-trial. We measured correct response times, eye movements (Experiment 1), and SSVEPs (Experiment 2) from healthy participants, and correct response times from visual neglect patients (Experiment 3). Results: When the mean size of the array remained stable over time, visual search was facilitated in both healthy participants (faster correct response times, fewer saccades, larger pupil sizes), and patients (faster correct response times), and the amplitude of both target- and background-related SSVEP amplitudes (indexing attentional allocation) were attenuated. Conclusions: Our results provide evidence that statistical representations can create a stable context, freeing limited capacity attentional resources to perform a perceptually demanding search task. Furthermore, results suggest statistical summaries of peripheral information may play a central role in visual perception.

Acknowledgement: The research was supported by a European Research Council (ERC) grant (grant agreement no. 313658).

43.445 **Grouping by Temporal Structure: Perceptual Organization Without Awareness?** Sharon E. Guttman[1](sharon.guttman@mtsu.edu); [1]Department of Psychology, Middle Tennessee State University

The perception of coherent objects depends on grouping local image features into global spatial forms. Numerous cues support visual grouping, including similarity, spatial proximity, and common temporal structure, but knowledge of how the visual system combines these various sources of information remains limited. The current study investigates the extent to which grouping can occur without awareness of the cues that gave rise to the perceived organization. Observers viewed arrays of Gabor patches in which the spatial frequency of the elements changed stochastically over a one second trial. Within the array, a randomly positioned rectangle, oriented horizontally or vertically, grouped separately from the background elements. On some trials, this rectangle was defined by a temporal structure cue alone: all elements within the array were randomly oriented, but the figure elements followed one point process, while the background elements followed a different point process. On other trials, the rectangle was defined by a similarity cue alone: all elements within the array changed simultaneously, but the orientations of the figure elements were similar to one another, and differed from the orientations of the background elements. In a third condition, both temporal structure and similarity defined the figure. In several experiments, observers reported the orientation of the perceived figure, and judged which cue or cues triggered the organization. The results suggest that although both similarity and temporal structure strongly supported grouping, observers could not reliably identify the grouping cues; judgments of the temporal structure cue as present correlated more strongly with perceived figure strength than with the actual presence of the cue. These findings will be discussed in the context of ongoing discussions concerning potential mechanisms for stimulus binding.

43.446 **Hemispatial asymmetries of grouping effects on numerosity perception** Lixia He[1](lxhe@cogsci.ibp.ac.cn), Tiangang Zhou[1], Yan Zhuo[1], Lin Chen[1]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Biophysics, Chinese Academy of Sciences

Previous research has showed that numerosity perception is influenced by the grouping of to-be-counted items in a visual display. When items are connected or enclosed by a line, there is an underestimation for the item numerosity and the more items are connected or enclosed, the more underestimation there is. In the present study, we examined whether there were differential grouping effects in the left and right visual fields when dot displays were presented at different time scales (50, 100, 200 and 1000 ms). We used a magnitude comparison task in which two patterns were simultaneously presented on the two sides and participants had to judge which of the two patterns contained more dots. Among different experiments we presented displays that were grouped by connectivity (Experiment 1) or common enclosure (Experiment 2). We demonstrate that there was consistent numerical underestimation for the displays where some of the dot elements were grouped, and the overall grouping effects decreased with the increase of the stimulus presentation duration. Moreover, there was a stronger grouping effect in the right visual field over that in the left for both connectivity and common closure. These results are consistent with the finding that the left hemisphere is superior to the right hemisphere for global perception of topological properties which include connectivity and common enclosure (Wang, 2007).

Face perception: Experience, learning and expertise 1

Monday, May 19, 8:30 am - 12:30 pm
Poster Session, Pavilion

43.501 **Change in asymptote reveals distinct mechanisms underlying adaptation to faces** Yihwa Baek[1](baekx055@umn.edu), Stephen A. Engel[1]; [1]Department of Psychology, College of Liberal Arts, University of Minnesota

Viewing a face can alter the appearance of subsequently seen faces. These adaptation effects may serve to calibrate a norm-based representation of faces, where individual instances are coded relative to an average face. The mechanisms controlling adaptation to multiple faces remain relatively unexplored, however. Here we demonstrate that the visual system can maintain adaptation to a first face while simultaneously fully adapting to a second one. Subjects viewed distorted faces and judged whether their eyes were either closer together than normal or further apart than normal. We measured the point of subjective equilibrium (PSE) where subjects were equally likely to respond "too close together" as they were "too far apart." On each trial a 2 sec presentation of an adapting face was followed by 0.2 sec presentation of a test face, and the distance between the eyes in the test face was increased or decreased by 0.064 deg using a staircase procedure. Following eight min of adaptation to the eyes-too-close face, subjects' average PSE shifted by 0.28 deg from a no-adaptation baseline, asymptoting at this level after approximately 1.3 min. When this same eight min of adaptation was preceded by 30 min of adaptation to an eyes-too-far-apart face, the PSE shifted by only 0.12 deg, asymptoting after approximately 3 minutes (difference in asymptotic levels, $p < 0.05$). If adaptation to both faces were affecting the same mechanism, then a long enough period of eyes-too-close adaptation should be able to return the system to its previously attained asymptote. Its failure to do so implies that some amount of the initial adaptation effect is maintained even while the later adaptation reaches asymptote. This maintenance may occur at earlier stages of the visual processing hierarchy, where features of the eyes-too-close and eyes-too-far-apart faces differ and can be affected by adaptation independently.

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43.502 **The effect of visual familiarity on the implicit learning of prototype and eigenfaces** Xiaoqing Gao[1](xgao@cvr.yorku.ca), Hugh Wilson[1]; [1]Centre for Vision Research, York University

The human visual system implicitly learns statistical regularities from the environment. Our previous study demonstrated that central tendency (prototype) and at least the first two principal components (eigenfaces) are more efficiently learned from a group of newly encountered faces than the actually studied faces (Gao & Wilson, 2013), which provides an efficient mechanism for encoding new facial identities at an individual level. However, it is not clear whether the prototype and eigenfaces also play an essential role in encoding familiar faces. In the current study, we investigate the effect of visual familiarity on the learning of the prototype and eigenfaces. Adult participants (N = 31, mean age = 20 ± 2.6 years, 13 males) studied 16 synthetic faces in four successive learning sessions. In each session, each face was studied for 20 seconds over four presentations. We measured participants' memory performance after each learning session using an old/new recognition paradigm with the new faces sampled from an orthogonal volume of the face space relative to the studied faces. We also measured participants' false memory for the unseen prototype face and eigenfaces of the first principal component of the studied faces after the first and the fourth learning sessions. Participants' memory for studied faces improved from a moderate level (Hit = 0.60, FA = 0.22) after the first learning session to ceiling (Hit = 0.91, FA = 0.06) after the third learning session. However, the false recognition rates for the unseen prototype face and eigenfaces did not change between the first and the fourth learning sessions, and in both cases were higher than the recognition rates of the studied faces (ps<0.05). The results suggest that even with increased familiarity of the studied faces, prototype and principal components still play a crucial role in encoding individual facial identities.

Acknowledgement: This research was supported in part by CIHR grant #172103 and a grant from the Canadian Institute for Advanced Research to HRW.

43.503 **Invariance across view-points and viewing distances, and its effects on face perception—evidence from personally familiar face processing** Meike Ramon[1](m.ramon@psy.gla.ac.uk); [1]University of Louvain, Belgium & University of Glasgow, United Kingdom

Face identification is possibly the most complex, and likewise efficient task achieved by the human visual system. Studies addressing the effects of face familiarity have documented that the presence of facial representations in memory generally enhances processing efficiency. Nevertheless, it remains fairly unknown how visuo-perceptual processing of personally familiar and unfamiliar faces actually differs. The present study sought to identify sources of facial information that are processed differently due to repeated, real-life experience. The underlying hypothesis was that encountering faces across various viewpoints and distances enhances perception of facial information maintained across such changes. Variations in viewing distances affect the resolution of available information (Sinha et al., 2006; Gilad-Gutnick et al. 2012), while maintaining the overall configuration of facial features. Changes in viewpoint, on the other hand, do not affect the arrangement of facial information along the vertical axis (Dakin & Watt, 2009; Goffaux & Dakin, 2010). Four experiments were conducted testing individuals of the same peer group; i.e. all participants viewed identical stimulus sets containing a minimum of 20 personally familiar identities. The results demonstrate that while processing of local information is unaffected by familiarity, it leads to superior discrimination of the spatial relations maintained either across viewing distances (i.e. the overall configuration of internal features), or viewpoint changes (i.e. inter-feature relations along the vertical axis). These findings are compatible with a multi-dimensional face space (MDFS; Valentine, 1991) account of experience-dependent visuo-perceptual processing differences. Within the MDFS increased real-life experience concurs with enhanced diagnosticity of specific dimensions—those invariant to variations occurring during social interactions. This renders the facial representations of frequently encountered, personally familiar individuals more distinct and robust, as compared to those of unfamiliar ones.

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43.504 **Face Matching Skill: Studies of Individual Differences and Training** Anne Hillstrom[1](anne.hillstrom@port.ac.uk), Gary Dalton[2], Lorraine Hope[1], James Sauer[1]; [1]Department of Psychology, University of Portsmouth, [2]Institute of Criminal Justice Studies, University of Portsmouth

Deciding whether two pictures depict the same unknown person is surprisingly difficult. The work presented here explored individual differences in the task and potential methods of training people to do the task better. A set of stimuli were developed that include age changes as well as photographic differences. A cross section of people were tested to identify people particularly skilled at face matching. The skilled matchers were interviewed and their eye movements were measured. We compared a training method where those eye movements were used to model effective inspection of the faces with more traditional training methods. Learning was tested immediately after the training, a week later and three weeks later. Effectiveness of training was tested using faces out of the same corpus and faces from a different, easier, corpus. Results showed that inspection modelling was most effective at improving perforrmance in the easy corpus. No training improved comparisons that were difficult. There were negligible differences in eye movements between those with high accuracy and those with average accuracy. Demographic characteristics that were related to skill will be presented, as will the kinds of strategies used.

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43.505 **Adaptation to an average expression improves discrimination of facial expressions** Nichola Burton[1](nichola.burton@uwa.edu.au), Linda Jeffery [1], Andrew Calder[2], Gillian Rhodes[1]; [1]ARC Center of Excellence in Cognition and its Disorders, School of Psychology, The University of Western Australia, [2]MRC Cognition and Brain Sciences Unit

Adaptation serves an important calibrating function in low-level vision, allowing efficient coding of a wide range of stimulus levels and enhancing discrimination around the adapted level. Adaptation is also present in high-level face perception processes such as expression perception, but the functional benefit of this adaptation has not been consistently demonstrated. Here we show that adaptation to an average expression improves discrimination around that average. We created a morphed expression trajectory that ran from fear, through an average expression, to anti-fear. Twenty-three participants were trained to recognize the two endpoint expressions and the average expression using arbitrary labels. They then categorized a range of briefly-presented expressions taken from this trajectory in three conditions: with no adaptation (baseline), after 160 s of adaptation to the average expression, and after 160 s of adaptation to the alternating endpoint expressions. A size change was included to minimize the effect of low-level adaptation. Thresholds were calculated for the detection of each endpoint expression; the distance between these thresholds on the trajectory served as a measure of expression discrimination. Following adaptation to the average expression, the inter-threshold distance narrowed significantly relative to baseline, indicating better discrimination around the average in this condition. In contrast, adaptation in the alternating condition did not change the inter-threshold distance relative to baseline, suggesting that our finding cannot be explained by a priming effect. Overall, our results demonstrate a functional role for adaptation in high-level expression perception.

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43.506 **Testing the face-specificity of the inversion effect in budgie experts** Alison Campbell[1](campbel1@uvic.ca), James Tanaka[1]; [1]University of Victoria, British Columbia

Dramatic inversion costs in the recognition and perception of faces but not objects have reinforced the view that face-specific mechanisms support holistic processing for face individuation. The alternative expertise hypothesis asserts that these effects, while appearing face-selective, reflect domain-general processing strategies for expert perceptual discrimination. Previous studies of real-world object expertise have been restricted to the context of within-class object discrimination (e.g. car model, bird and dog species), providing a weak test of the expertise hypothesis with respect to perceptual individuation. In this study, we examined a novel form of expertise in bird breeders who individuate highly homogenous birds at the identity level. Breeders of show budgies maintain aviaries of 50-300 birds with each bird being uniquely recognized based on physical characteristics such as markings and body structure. Information about each bird's relation to the social and genetic structure of the bird group is also attached to this recognition. Performance in a sequential matching task for upright and inverted birds and faces was compared across

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experts and novices. Results show that budgie experts outperform bird novices in the perception of upright bird images, yet this increased perceptual ability is orientation specific and is impaired for inverted bird images. These results demonstrate that inversion effects can be found for objects which are individuated and visually homogenous, and support the hypothesis that inversion costs for faces are a consequence of domain-specific experience and not necessarily due to a face-specific mechanism.

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43.507 **Fido-specific after-effects: Dog specific adaptation for dog-owners but not non-owners.** Sarah Laurence[1](slaurence@brocku.ca), Victoria Ratcliffe[2], Graham Hole[2], David Reby[2], Catherine Mondloch[1]; [1]Department of Psychology, Brock University, [2]School of Psychology, University of Sussex

Exposure to a distorted face results in subsequently viewed distorted faces appearing more normal. This type of face adaptation has been used extensively to probe our representations of human faces. In Experiment 1 we used the face distortion after-effect (FDAE) to explore the role of experience in the processing of unfamiliar individuals from a different species, the domestic dog (Canis familiaris). We adapted our participants to the distorted face of a golden retriever and tested their subsequent normality judgments for various dogfaces that matched the adapting stimulus in identity (both the same and a different image of the same dog), breed, colour (but not shape), shape (but not colour), or in species only (i.e., neither shape nor colour). After adaptation there was a different pattern of normality judgements for dog owners compared to non-owners. Dog owners (n=30) showed a larger FDAE than non-owners (n=25) for same-identity images. The dog owners' FDAE was identity-specific: it was equivalent in size for the same-identity images and transferred significantly less to all other dogs (regardless of breed, shape and colour). For non-owners, the FDAE was equivalent in size for all dogs that were similar in colour (e.g. pale fur with a dark nose). Experiment 2 was conducted to further investigate the role of experience by comparing the FDAE for golden retriever owners and owners of other breeds. Data to date (n=7) suggests a golden retriever-specific effect; the FDAE was more specific for golden retriever owners than it was for owners of other breeds. The findings suggest that experience with different types of faces can affect whether they are represented at a more basic level (e.g., a pale dog) or subordinate level (e.g., an individual golden retriever).

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43.508 **The influence of perceptual expertise on object aftereffects: the case of faces, birds and cars** Linda X Wang[1,2](lxwang23@gmail.com), Jason JS Barton[1,2], Jodie Davies-Thompson[1,2]; [1]Department of Medicine (Neurology), University of British Columbia, [2]Department of Ophthalmology and Visual Sciences, University of British Columbia

Background: High-level aftereffects can be used to explore the nature of object representations in the human visual system. Whether increased expertise for one object category leads to changes in aftereffects for that category is uncertain. Also, given the potential for competition between representations of different objects, expertise for one category may lead to changes in aftereffects for other objects. Hypothesis: We examined first whether expertise for a category of objects like cars or birds is associated with better discrimination with morphed images of the expert category, or an increase in aftereffect magnitude for that category. Second we examined if discrimination or aftereffect magnitude was reduced for other categories. Method: We tested 30 subjects who were bird experts (n=10), car experts (n=10), or non-experts (n=10). All subjects also received independent tests to confirm perceptual expertise for faces, cars and birds. To assess discrimination and aftereffects, we used a perceptual bias adaptation technique to probe identity aftereffects with morphed stimuli of human faces, birds, and cars. Results: First, the ability to discriminate structural changes differed between the groups only for birds, where the bird experts showed superior discrimination compared to car experts and non-experts. Second, the magnitude of the adaptation for each of the three object categories did not vary with subject group. Finally, at an individual subject level, there was a correlation between the magnitude of aftereffects for faces and birds. Conclusion: These results provide some support for sharpened discrimination as a consequence of expertise, mainly for birds. However, they do not suggest that discriminative ability for non-expert categories suffers as a consequence of perceptual expertise in another category: in fact, there was a positive correlation between the two natural-object categories, faces and birds. Aftereffect magnitude does not appear to be altered as a consequence of perceptual expertise.

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43.509 **Computer generated faces may not tap face expertise** Kate Crookes[1](kate.crookes@uwa.edu.au), Louise Ewing[1], Ju-dith Guildenhuys[1], William Hayward[1,2], Matt Oxner[2], Stephen Pond[1], Gillian Rhodes[1]; [1]ARC Centre of Excellence in Cognition and Its Disorders, School of Psychology, University of Western Australia, [2]Department of Psychology, University of Hong Kong

The use of computer-generated (CG) faces in research is proliferating due to the ease with which they can be generated, standardised and manipulated. However there has been little research into whether CG faces are processed in the same way as photographs of real faces. The present study investigated whether the other-race effect (ORE) – a well-established finding that own-race faces are recognised more accurately that other-race faces – is observed for CG faces. We started with a set of male Caucasian and Asian face photographs that have produced the ORE in Caucasian and Asian participants in previous studies (Real condition). These faces were imported into FaceGen, a widely used CG face generating software program, to produce a CG version of each (CGReal condition). Finally a set of wholly artificial male faces were randomly generated using FaceGen (CGArtificial condition). In Experiment 1 Caucasian and Asian participants completed a recognition memory task for own- and other-race Real, CGReal and CGArtificial faces. Overall memory performance was dramatically reduced for both CG conditions compared to Real faces and the ORE was attenuated for CG faces. CG faces were also rated as significantly less distinctive than Real faces. Experiment 2 used a simultaneous line-up task to explore the ORE on perceptual matching for Real and CGReal faces in Caucasian and Asian participants. Again overall performance was reduced for CG compared to Real faces. Together these results suggest that the loss of detail and reduced distinctiveness of computer-generated faces affects the usefulness of these stimuli for any studies designed to investigate face processing.

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43.510 **Beyond perceptual expertise: Revisiting the neural substrates of expert object recognition** Assaf Harel[1](assaf.harel@nih.gov), Dwight Kravitz[2], Chris Baker[1]; [1]Laboratory of Brain and Cognition, National Institute of Mental Health, [2]Department of Psychology, George Washington University

Real-world visual expertise provides a valuable opportunity to understand how experience shapes human vision and neural function. In object recognition, expertise is commonly viewed as modifying stimulus-driven perceptual processing in visual cortex. One prominent version of this perceptual perspective has focused almost exclusively on the relation of expertise to face processing. In terms of the neural substrates, this perceptual view has centered on face-selective cortical regions, particularly the Fusiform Face Area (FFA). In contrast to this view, we report recent behavioral and neuroimaging (both structural and functional) evidence, which highlights the critical role that high-level factors, such as attention and conceptual knowledge play in object expertise. Together, these studies demonstrate that expert related activity is i) found throughout visual cortex, not just FFA, with a strong relationship between neural response and behavioral expertise even in the earliest stages of visual processing, ii) found outside visual cortex in areas such as parietal and prefrontal cortices, and iii) modulated by the attentional engagement of the observer suggesting that it is neither automatic nor driven solely by stimulus properties. Based on these diverse lines of evidence, we propose a novel view of object expertise, the interactive account, suggesting that object expertise emerges from extensive interactions within and between the visual system and other cognitive systems, resulting in widespread, distributed patterns of expertise-related activity across the entire cortex.

Acknowledgement: NIMH Intramural Research Program

43.511 Measurement of semantic knowledge of object categories: Creating the Semantic Vanderbilt Expertise Test (SVET) Ana Van Gulick[1](ana.e.van.gulick@vanderbilt.edu), Isabel Gauthier[1]; [1]Department of Psychology, Vanderbilt University

A growing interest in individual differences in face and object recognition motivates the development of visual learning tests such as the Cambridge Face Memory Test (Duchaine & Nakayama, 2006) and the Vanderbilt Expertise Test (VET; McGugin et al., 2012). But experience with a category may also result in non-perceptual knowledge. We seek a reliable and valid measure of non-perceptual semantic knowledge in a standard format for a variety of object categories (rather than one category, Barton et al. 2009; Van Gulick & Gauthier, VSS2013) that applies to the full range of expertise in a domain. The Semantic Vanderbilt Expertise Test (SVET) focuses on one aspect of semantic knowledge that can be measured across categories: acquisition of relevant nomenclature. Each trial consists of a triplet of names, one real name of an object in that category and two foils. The SVET 1.0 includes 7 categories: birds, cars, dinosaurs, planes, shoes, Transformers, and trees. Through multiple iterations of data collected on Amazon Mechanical Turk test items were fine-tuned based on factor analysis, classical item analyses, and item response theory. In data from samples of 96-101 subjects per category, all tests showed good internal consistency (Cronbach's alpha). We validated each SVET against subjects' self-reports of their category knowledge, assessed with 7 domain-specific questions (Gauthier et al., submitted). Across all categories, subjects' general rating of their category experience was most strongly correlated with SVET performance (r=.38) followed by their rating of how detailed an essay they could write about the category (r=.35). Interestingly, just like perceptual performance on the VET, the SVET correlation with age and gender differed across categories, suggesting a role for experience. The SVET can provide assessment of semantic knowledge to complement visual measures, and to help understand how performance is determined by the interaction of perceptual and cognitive abilities with experience.

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43.512 Modeling the Moderation of Experience in Face and Object Recognition Panqu Wang[1](pawang@ucsd.edu), Benjamin Cipollini[2], Akinyinka Omigbodun[1], Isabel Gauthier[4], Garrison Cottrell[3]; [1]Deparment of Electrical and Computer Engineering, University of California, San Diego, [2]Deparment of Cognitive Science, University of California, San Diego, [3]Deparment of Computer Science and Engineering, University of California, San Diego, [4]Department of Psychological Sciences, Vanderbilt University

Recent work suggests that the recognition of faces and non-face objects depend on independent abilities, based on little shared variance between performance on measures of face recognition (e.g., the Cambridge Face Memory Test, CFMT) and of non-face object recognition (Wilhelm et al., 2010; Wilmer et al., 2010; Dennett et al., 2011). Gauthier et al. (VSS2013; submitted) challenged this idea, arguing that a domain-general ability (v) underlies face and object recognition, but that this ability is expressed with a category only when people have sufficient experience in that category. They collected self-ratings of experience for 8 categories, measured perceptual performance on these categories using the Vanderbilt Expertise Test (VET; McGugin et al., 2012) and on the CFMT. As experience grows, the shared variance between the CFMT and VET increased monotonically. When subjects have considerable experience with objects, if they perform poorly (well) with objects, they also perform poorly (well) on faces (Figure 1). Here we show that our neurocomputational model of face and object recognition ("The Model", (TM), Dailey & Cottrell, 1999) can account for these results. Input stimuli go through Gabor filter banks and PCA as preprocessing, followed by an error-driven artificial neural network as training. We map "domain general ability" (v) to the number of hidden units, and "experience" (E) to the number of training epochs of new objects in TM. We train on faces first, and then on another non-face category at the subordinate level. We test our model on 4 different object categories: faces, butterflies, cars and leaves. We show that the shared variance between the performance of face expert and all non-face experts increases as experience grows, which matches Gauthier et al.'s result qualitatively. Our results suggest that a potential source for variance in v between subjects is the amount of representational resources.

43.513 Gender effects for toy faces reveal qualitative differences in face processing strategies Kaitlin Ryan[1](kaitlin.ryan@vanderbilt.edu), Isabel Gauthier[1]; [1]Department of Psychology, Vanderbilt University, Nashville, Tennessee, 37240, USA

Previous research suggests an advantage for women over men in recognizing faces. (Lewin & Herlitz, 2002; Bowles et al. 2009). However, this ignores the variety of face types and varied experience with these faces. McGugin et al. (2012) showed how using performance for several object categories led to a different interpretation of sex differences, one emphasizing the role of experience, compared to an approach where differences are obtained for a single category, and interpreted as due to general visual or cognitive mechanisms (Dennett et al., 2010). Here, we apply similar logic to faces to explore sex differences in face recognition that may be influenced by relative experience with face categories. We developed the Vanderbilt Face Expertise Test (VFET), based on the format of the Vanderbilt Expertise Test (VET; McGugin et al. 2012) and the Cambridge Face Memory Test (CFMT; Duchaine & Nakayama, 2006). In 480 participants (181 male), we measured recognition performance for 4 face categories (Barbies dolls, Transformer action figures, Caucasian males, Caucasian females) and cars. For each category, participants studied 6 targets and found them among pairs of distractors on 48 trials. Women outperformed men with Barbie faces (Sex * Category interaction, F(1,355)= 14.92, p=.0002) and men outperformed women with Transformer faces (F(1,353)= 5.92, p=.016). Moreover, multiple regressions suggested qualitative differences in performance on toy categories; men's performance on toy faces was predicted by performance on other toy categories, whereas women's performance was predicted by performance with human faces. While prior work with faces finds an advantage for women or no gender effect, we find a face category for which men outperform women, suggesting that experience may drive prior gender effects. Furthermore, the results suggest that experience with faces may not only influence overall performance, but may result in qualitative differences in how men and women recognize faces.

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43.514 How does reading direction modulate perceptual and visuospatial attention biases? Harry Chung[1](hkschung2@gmail.com), Joyce Liu[1], Janet Hsiao[1]; [1]Department of Psychology, The University of Hong Kong

Left-side bias (LSB) effects have been reported in different tasks. For example, in perceptual judgments of faces, participants typically judge a face made from two left half-faces more similar to the original face than one from two right half-faces (chimeric face task). A similar effect was observed in Chinese character perception in expert Chinese readers (chimeric character task; Hsiao & Cottrell, 2009). LSB effects were also commonly observed in visuospatial attention tasks. For example, in the greyscales task with two horizontal bars, participants typically judge the bar darker on the left side to be darker overall than the one darker on the right, although they are equiluminant. In line bisection, participants tend to bisect lines slightly to the left of the real center. It remains unclear whether reading direction plays a crucial role in the bias effects. Some previous studies compared readers of languages read from left to right with those read from right to left (e.g., French vs. Hebrew); nevertheless, their differences may be due to cultural differences, for example, instead of reading direction. Although Chinese is typically read from left to right, in contrast to other languages, it can also be read from right to left. Thus, Chinese provides a unique opportunity to examine the influence of reading direction within subjects. Chinese participants performed perceptual bias (chimeric face and character tasks) and visuospatial attention bias tasks (greyscales and line bisection) once before and once after reading direction priming, in which they read Chinese passages from right to left for about 20 minutes. Participants showed significantly reduced LSB in perceptual bias tasks but not in visuospatial attention bias tasks after the priming. Thus, reading direction does not seem to influence visuospatial attention biases as much as perceptual biases, suggesting that these two forms of biases involve different underlying mechanisms.

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43.515 Painted faces: misperceiving shading as pigmentation Amy Mac[1](amyjasminemac@hotmail.com), Katherine Tregillus[1], Frederick A. A. Kingdom[2], Michael A. Webster[1]; [1]Department of Psychology, University of Nevada, Reno, [2]Department of Ophthalmology, McGill University

Many lightness illusions reflect the discounting of shadows and shading by the visual system so that equivalent luminances appear as different lightnesses; or conversely, cases where shadows are not discounted

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because they are instead misperceived as surfaces. We explored a novel form of these illusions created simply by mirroring side-lit objects. When the two halves of a side-lit face are each mirrored to form a pair of symmetric faces, the face formed by the shaded side is perceived to be darkly pigmented. These effects can be measured by a matching task in which observers adjust the lightness or texture of a uniform comparison patch to match the perceived skin tone on either side of the face. The matches are similar for the two sides of the original side-lit face, yet can strongly differ between the two mirrored faces. The magnitude of the illusion is dependent on cues to the actual angle and directionality of the illuminant, as well as the surface structure of the object, and we explore the inferences and stimulus cues underlying this dependence. For example, the effect is largely absent in simple shapes such as uniform spheres, and for faces depends critically on the point at which the image is mirrored and on which directly lit surfaces this includes. Notably, when only one side of the face is shown, the shaded side again defaults to a pigmented percept, though this again diminishes rapidly as cues to the actual lighting are included.

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43.516 **Evidence for opponent coding of hand-identity within a multidimensional 'hand-space'** Federica Biotti[1,2](fedebiotti@gmail.com), Richard Cook[1]; [1]Department of Psychology, City University London, [2]Department of Psychological Science, Birkbeck College, University of London

In recent years there has been much speculation that facial identities are represented within a multidimensional 'face-space'. According to this framework, the perception of facial identity is determined by the relative excitation of opponent cortical populations, tuned to complementary facial attributes. Consistent with this view, adapting to a particular facial identity systematically biases perception towards its anti-face – the corresponding identity on the opposite side of the population mean. Using a psychophysical adaptation procedure, the present study sought to determine whether exemplars of other body parts are also represented relative to an average, within a multidimensional space. Fifty images of male hands were first described in terms of their shape and texture variation and then subjected to principal components analysis (PCA). Two pairs of anti-hands were subsequently created by reconstructing hand identities corresponding to ±2 standard deviations along the axes defined by the odd and even principal components comprising the computed "hand-space." These 4 images were used as adapting stimuli in an adaptation procedure. Trials presented an adapting stimulus for 10 seconds, followed immediately by a test stimulus, presented for 1 second, taken from either a congruent or orthogonal morph continuum. Observers made binary-choice judgments about the identity of the test hand. Perceptual bias was inferred from the point of subjective equivalence (PSE) on the resulting psychometric functions. Adapting to a particular hand identity was found to selectively bias perception of subsequently viewed test stimuli in the direction of the anti-hand. No systematic bias was detected in the orthogonal direction. These results are analogous to similar findings with facial identity and accord with recent suggestions that faces and bodies may recruit similar perceptual mechanisms.

Perception and action: Decisions, interception

Monday, May 19, 8:30 am - 12:30 pm
Poster Session, Pavilion

43.517 **Action relations affect affordance selection: Evidence from visuomotor responses to paired objects** Shan Xu[1](sxx127@bham.ac.uk), Dietmar Heinke[1], Glyn Humphreys[2]; [1]School of Psychology, University of Birmingham, [2]Department of Experimental Psychology, Oxford University

The implied actions between objects affect object perception by grouping these objects into perceptual units (e.g. Riddoch et al., 2003). The present study extended this line of investigation and examined the influence of implied actions on the automatic sensorimotor response to each involved object. Similar to studies on affordance-based effects of single objects (e.g. Philips & Ward, 2002), we presented pairs of task-irrelevant objects which are typically used together (e.g. a jug and a cup). Then imperative target was added on the screen centre. In response to the shape of the target (square/triangle), the participants made speeded left/right responses. Thus the responses were aligned with objects' positions on the screen. The implied actions between objects were manipulated by varying the orientation of one of the objects, leaving the co-location of objects correct or incorrect in terms of the afforded actions. When the co-locations of objects were correct, responses compatible with active objects (e.g. jug) were quicker than those compatible with passive objects (e.g. cup). The correct co-location slowed down responses compatible with the passive objects compared to when the co-location was incorrect. Little evidence was found for the effect of response modality (between-hand in Experiment 1 and 2, within-hand in Experiment 3 and reaching-and-grasping in Experiment 4), suggesting that visuomotor responses to paired objects were less dependent on activating the exact motor program of the afforded action than on the congruency between spatial codes of the responses and the stimuli. Our results suggested that the active objects in action-related object pairs dominate the visuomotor responses to the visual scene, and inhibit the visuomotor responses to the passive objects. These results underline the contextual influence on the selection of affordance, suggesting that action relation between objects might be a critical factor for determining the visuomotor representation of objects in visual scenes.

43.518 **Bayesian Theory of Action-Specific Effects Suggests Integration of Visual- and Action-based Information** Jessica Witt[1](jessica.witt@colostate.edu); [1]Colorado State University

The action-specific account of perception emphasizes the role of action in perception. The claim is that perceivers see the spatial layout of the environment in terms of their ability to perform the intended action. For example, when trying to block balls moving at various speeds, the balls look to be moving slower when the paddle used to block them is bigger and thus more effective at blocking (Witt & Sugovic, 2010, 2012, 2013). Yet to be determined is how action-based information exerts its influence. According to Bayesian theory, if two sources of information (such as action-based and visual information) are integrated, one source will exert a greater influence as uncertainty related to the other source increases. To test this, I took a novel approach by leveraging naturally-occurring individual differences in uncertainty. Participants (N = 62) attempted to block balls moving at various speeds with different sized paddles and estimated the speed of the ball. The point of subjective equality (PSE) was calculated for each paddle condition for each participant, and the difference in PSEs between the big and small paddles served as the measure of the action-specific effect. A bigger PSE difference score indicates a larger effect of paddle size on speed judgments. Just-noticeable differences (JNDs) were calculated for each participant across all trials and were used as a measure of uncertainty related to visual information. There was a positive correlation ($r = .55$, $p <.001$) between PSE difference scores and JNDs: as visual uncertainty increased, the action-specific effect also increased. According to Bayesian theory, this result suggests that action-related information is integrated directly with visual information.

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43.519 **The role of basic visual features in priming** Fredrik Allenmark[1](fredrik.allenmark@gmail.com), Karolina Moutsopoulou[1], Florian Waszak[1]; [1]Laboratoire Psychologie de la Perception, Université Paris Descartes, Paris, France

It has been demonstrated that humans can learn associations between a stimulus and a response such that they can respond faster when the same response is again required to the same stimulus (the priming effect). Such priming effects can be separated into effects of stimulus-task associations and stimulus-action associations (Waszak, Hommel, Allport 2003; Moutsopoulou and Waszak 2012). Here we wanted to examine whether repetition of the basic features of a visual stimulus, such as colour, is important for priming effects on task and/or action or if repetition of shape is sufficient. The stimuli were images of objects the shape of which was defined by a region in a dynamic random dot stereogram where dots were given a different colour and binocular disparity from the background. This region was slightly shifted between frames to create motion of the entire image without motion of individual dots. The participants' had to perform one of two tasks, such as judging the size of the object, each with two possible responses. A cue displayed before each image indicated which task to perform and which key to use for each response. Each object was displayed three times: two prime and one probe presentation. Each stimulus feature, the task and the mapping between response and key-press was either switched or repeated between the second prime and the probe. We found an overall reduction in reaction times with repeated presentations (priming effect) and this effect was smaller when the classification or action was switched. However, there was no significant difference associated with switching the stimulus features nor was there an interaction between task or action switch and feature switch. This suggests that priming does not occur at the level of the basic features defining a visual stimulus but at a later level of stimulus processing.

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43.520 Examining decision heuristics in a timed visuomotor task
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Timed visuomotor decisions require estimates of expected performance in order to choose an appropriate action. However, predicting performance in a task with multiple options (e.g., choosing which lane to travel on a crowded highway) is difficult. By the time we make a decision conditions may change. As a result it may be desirable to rely on strategies that speed the decision process without excessive cost to performance. To investigate these decisions, a computer mouse was used to aim and fire at a moving target before a deadline. Target velocity, size, and predictability of motion varied. When only one target was present, performance (hit rate, error, RT) depended on size, target velocity, and path predictability, with size having the largest effects. Reaction time was more correlated with size than hit rate. With two targets and instructions to hit only one, subjects choice of target was mostly rational in that most (75%) choices could be predicted by the relative probability of hitting either target as estimated from single target performance. Rational decisions and shorter RTs were much more likely when the difference between the probability of hitting the two targets was greater than .5. However there were biases; for example subjects tended to pick a larger target even when it had a lower probability of being hit. As in the single target case, larger targets also tended to elicit shorter RTs which may have contributed to the bias to pick large targets. These results suggest that internal estimates of performance are accessible for making perceptual-motor decisions. However, subjects sometimes relied on heuristics based on more perceptually accessible information (size) as well as the expected duration of planning and executing the movement.

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43.521 Visual and motor priming effects on prediction of observed action in the first and third person perspectives
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Much evidence demonstrates the existence of a neural network of action-observation shared representations (Rizzolatti & Craighero, 2004). It has been posited that this action-observation network (AON) allows us to draw upon one's own motor repertoire to facilitate prediction and interpretation of others' actions (Wilson & Knoblich, 2005). If the network's function is specifically for social understanding, then action observation should be more accurate in a third-person perspective (3PP) compared to a first-person perspective (1PP). In Experiment 1, participants viewed short action sequences of transitive actions; a hand reaching towards, grasping and removing an object from a table. The action was transiently occluded for 500ms, after which the sequence continued with an offset of between -200ms and 200ms. Participants responded whether the continuation of the action began from a point that was earlier or later than expected. Fitting logistic functions to participants' responses demonstrated no significant difference in the point of subjective equality (PSE) between the 1PP and 3PP observed actions. In Experiment 2, prior to the same computer task, the 3PP action was primed by participants observing the experimenter perform the transitive actions. This produced an overall improvement in accuracy, but again there was no difference in PSE between perspectives. In Experiment 3, participants performed the actions themselves before completing the same task. This produced a significant difference in PSEs for 1PP and 3PP observed actions ($t(23) = -2.7$, $p = .01$), with motor priming preferentially improving temporal prediction of actions observed in the 1PP. The findings suggest visual experience may predominantly be used to aid prediction of 3-PP actions, whilst the predictive mechanisms of the AON draw on the motor repertoire of the observer to facilitate predictions of 1PP actions. The study thus questions the notion that motor experience aids prediction of others' actions.

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43.522 Blind prediction of perceptual states using patterns of motor variability
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We heavily rely on information from our visual system to help coordinate our daily interactions in the environment. Yet, our understanding of how top-down visual processes modulate the execution of fundamental goal-directed and transitional motor actions remains unclear. Here we utilize a robust 3D depth inversion illusion (3D-DII) to explore how top-down processes influence reach dynamics when participants grab toward a target embedded in a 3D scene, specifically asking whether their motor action is governed by the 3D-DII's real or perceived geometry. Two 3D stimuli were used: (1) a proper-perspective (or forced perspective) in which perspective-painted cues were congruent with the bottom-up signals of binocular disparity and motion parallax, and (2) a reverse-perspective, in which the painted cues competed with bottom-up signals, eliciting bistable percepts of: (a) veridical depth and (b) illusory reverse-depth percept in which concave parts are perceived as convex and vice versa. The reverse-perspective 3D-DII generates nearly 90-degree differences in perceived surface orientation under veridical and illusory states, generating optimal conditions to explore differences in target approach. Subjects viewed the stimuli and grabbed at planar disk targets while we recorded their movements. Variability analyses of the normalized peak velocity in the arm's retraction reveal informative distributions that blindly separate reaches performed under illusory and veridical states under the reverse-perspective, as well as for reaches conducted on the proper-perspective stimulus. This provides compelling evidence for the effect of top-down processes on somatosensation, allowing for the blind separation of reaches performed under each perceptual state based on self-emerging motor signatures.

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43.523 The Effects of Speed and Direction on Eye-hand Coordination for Moving Targets
Melissa Bulloch[1](melissabulloch@gmail.com), Steven Prime[1,2], Jonathan Marotta[1]; [1]Perception and Action Lab, Department of Psychology, University of Manitoba, [2]School of Psychology, Victoria University of Wellington

Grasping moving objects involves both spatial and temporal predictions. The hand is aimed at a location where it will meet the object, rather than the position at which the object is seen when the reach is initiated. Previous eye-hand coordination research from our lab, utilizing stationary objects, has shown that participants' initial gaze tends to be directed towards the eventual location of the index finger. This experiment examined how object movement affects gaze and selection of grasp points. A computer-generated target (4 x 4 cm) was presented on either the left or right edge of a 24 in. monitor, and after a 1.5 s delay, travelled horizontally across the monitor at either a "slow" (5 cm/s) or "fast" (10 cm/s) speed. Participants reached to grasp the target upon hearing a tone presented either 2.5 s or 5 s after the target appeared. Results showed that when the target first appeared, participants anticipated the target's eventual movement by fixating ahead of its leading edge. Once target movement began, participants shifted their fixation to the leading edge of the target. Upon reach initiation, participants then fixated towards the top edge of the target. Final fixations tended towards the final index finger contact point on the target. ROI analysis, and examination of the extent to which the eyes reproduced the target's motion, revealed that it was direction that most influenced fixation locations and grasp points. Interestingly, it was found that participants fixated further ahead of the target's leading edge when the direction of motion was leftward, particularly at the slower speed—possibly the result of mechanical constraints of intercepting leftward moving targets with one's right hand. Our findings suggest differences between initial fixation locations (an anticipation effect), but similar preference for final fixation locations, when reaching to grasp moving versus stationary targets.

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43.524 Learned action effects modulate salience in space: Evidence for the preactivation theory
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Performing an action can reduce sensitivity to the sensory outcomes associated with the action. One explanation of this sensory attenuation effect, the preactivation account, proposes that action performance raises the activity of the internal representation of the action's sensory outcome, and that this heightened activity influences how incoming stimulus is processed. In particular, the stimulus-driven raise in neural activity is reduced for stimuli consistent with the activated representation, due to preactivation, compared with inconsistent stimuli that have no such preactivation. In this way, the stimulus-driven raise in neural activity hinders detecting a stimulus consistent with a learned action outcome. To test this account, we used a spatial attentional cuing phenomenon known as the attentional repulsion effect. In Experiment 1 we confirmed that when a cue is consistent with a learned action-outcome its effective salience is reduced (i.e., a smaller attentional repulsion effect) compared with a cue that is inconsistent with the action-outcome. Critically, the attentional repulsion effect paradigm allowed us to test the effect of action-induced activation of cue representation on the distribution of salience in space when action effects were no longer present. This was done In Experiments 2 and 3, we found that actions increase the salience of action-outcome locations even in the absence of action-outcomes. In other words, through learned action effects, we were able to generate attentional repulsion effects without the presence of the peripheral cues. These findings provide strong support for the preactivation account of action-induced sensory attenuation.

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43.525 **Titchener's T in Context – Delimited, Discrete Monomotif Patterns** Klaus Landwehr[1](landweh@uni-mainz.de); [1]Allgemeine Experimentelle Psychologie, Universität Mainz

Three experiments tested effects of self-similar contexts on the visual and haptic T-illusions (when both lines of a T are equally long, the undivided one appears to be longer than the divided one and is also haptically indicated longer). Experiment 1 used patterns of 4 Ts, Experiment 2 used branching patterns in which 4 Ts had been embedded, and Experiment 3 used patterns of 4 triangles and 4 catenary-derived forms for which the T constituted a skeleton. All patterns were of symmetry group c4, and all were presented at their 2 canonical orientations (all figure or skeleton lines horizontal or vertical or all of them oblique at 45 deg). Figures were scaled in size by factorially crossing 3 lengths of the Ts' lines, and patterns in Experiment 1 were also scaled in density. 3 independent samples of 12 observers each had to haptically indicate the lengths of selected target lines and verbally judge relative lengths of both types of lines of target Ts. The haptic illusion vanished with the branching patterns of Experiment 2, but the visual illusion persisted throughout, being stronger when the undivided line was target. Patterns as such and their density did not have great effects, suggesting that the causes of the illusions are local. Results from Experiment 3 suggest that in addition to interactions between orientation-sensitive neurons referring to the T's T-junction, the illusion may be caused by a discriminative response to different plane angles or different curvatures referred to the T's endpoints. The asymmetric visual illusion can possibly be explained in terms of priming.

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43.526 **The temporal balance between evidence integration and probabilistic sampling in perceptual decision making** Jeppe Christensen[1,2](jabbahc@gmail.com), Máté Lengyel[1,3], József Fiser[1]; [1]Department of Cognitive Science, Central European University, Hungary, [2]Center for Visual Cognition, Department of Psychology, Copenhagen University, Denmark, [3]Computational and Biological Learning Lab, Department of Engineering, University of Cambridge, United Kingdom

Models of evidence integration (EI) assume that the accumulation of external information alone is the dominant process during perceptual decision making until an overt response is made. In contrast, probabilistic sampling (PS) theories of the representation of uncertainty (Fiser at al. 2010) posit that time during perceptual decision making is primarily used for collecting samples from essentially static, internally represented distributions -- at least for briefly presented simple stimuli. While EI predicts a decreasing trend in the correlation between participants' estimation error and uncertainty over a trial, PS predicts an increasing trend even long after error and uncertainty reach asymptotic values. The predictions of PS have recently been confirmed in experiments using static stimuli (Popovic et al. 2013). However, the precise relationship between EI and PS in the more general case of dynamic stimuli have remained unexplored. To dissect the contributions of EI and PS to perceptual decisions, we used a variant of the classical random dot motion task that required estimation (rather than discrimination judgment). In each trial, participants reported their best estimate for stimulus direction and their subjective uncertainty about it by the direction and length of a line drawn on a tablet. We controlled EI by varying the coherence of the signal (providing more or less evidence), and PS by varying the stimulus presentation time (allowing for the collection of more or less samples). In each participant, we found a marked decrease in error-uncertainty correlation in the first part of the trial, indicating EI, and a significant increase in the second part, indicating PS. Moreover, the transition between these segments shifted in accordance with the change in signal coherence. These results suggest that EI and PS during decision making work in parallel with EI taking the lead early but PS determining the later part of the process.

43.527 **Ups and downs: task-dependent timescale of evidence integration in environments with smooth, oscillatory probability changes** Friederike Schüür[1,2](f.schuur@nyu.edu), Peter F. Hahn[1], Laurence T. Maloney[1,2]; [1]Psychology, New York University, [2]Center for Neural Science, New York University

Accurate probability estimates based on sequentially observed outcomes are important for many, from visual to purely cognitive decision tasks. People can estimate probability by tracking outcome frequency. If probability is constant across time, people should give equal weight to each outcome. If probability changes, people should attribute less weight to or "discount" past outcomes (e.g. exponentially). Can people learn optimal, exponential discounting for a gambling and probability estimation task? On each trial, participants chose between a gamble – win 2 or loose 1 point – and a safe option – 0 points – and estimated their subjective probability of a positive outcome in the gamble (regardless of their actual decision to gamble). They received trial-by-trial feedback about the outcome of the gamble even if they opted for the safe option. Probability varied as a smooth sinusoid across trials (amplitude: 0.4; frequency: 0.01/trial). Too much discounting leads to high variability in probability estimates driven by noise and not by the underlying, changing probability. Too little discounting reduces sensitivity to noise but introduces a phase shift and amplitude reduction (bias) in estimates. We find task-dependent discounting: participants adapted to the changing probability but compared to optimal, they discounted too much in gambling and too little in estimation. Limited memory cannot explain task-dependency; rather participants may opt to reduce variability in overt estimation accepting bias. In one participant (~5%), we found reduction in noise-sensitivity without bias: only (s)he may have learned the sinusoid. In a follow-up, we trained participants in a slow (fast) change environment (frequency ~0.01 or ~0.02) and test in a fast (slow) change environment (counterbalanced). The task-dependency generalizes. When probed, participants report a preference for the trained and for the slow environment presumably reflecting a preference for, and awareness of, more certain probability estimates in slowly versus quickly changing worlds.

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43.528 **We know our own movement errors, but we hardly correct for then: An instance of optimal behavior** Marc Ernst[1](marc.ernst@uni-bielefeld.de), Loes van Dam[1]; [1]Bielefeld University, Cognitive Neuroscience & CITEC

Random errors are omnipresent in sensorimotor tasks due to perceptual and motor noise. The question is, whether humans are aware of their random errors on a trial-by-trial basis? The appealing answer would be 'no' because it seems intuitive that humans would otherwise immediately correct for their movement errors online, thereby increasing sensorimotor precision. However, here we show the opposite (van Dam & Ernst, PLoS One, 2013). Participants pointed to visual targets with varying degree of feedback. After movement completion participants indicated whether they believed they landed left or right of target. Surprisingly, participants' left/right-discriminability was well above chance, even without visual feedback (Experiment 1). Only when forced to correct for the error after movement completion did participants loose knowledge about the remaining error, indicating that random errors can only be accessed offline (Experiment 2). When correcting, participants applied the optimal correction gain, a weighting factor between perceptual and motor noise, minimizing end-point variance. Together these results show that humans optimally combine direct information about sensorimotor noise in the system (the current random error), with indirect knowledge about the variance of the perceptual and motor noise distributions. Yet, they only appear to do so offline after movement completion, not while the movement is still in progress, suggesting that during movement proprioceptive information is less precise.

43.529 **Active Sampling supported Comparison of Causal Inference Models for Agency Attribution in Goal-Directed Actions** Tobias F Beck[1](tobias.beck@uni-tuebingen.de), Dominik Endres[1,3], Axel Lindner[2], Martin A Giese[1,3]; [1]Department of Cognitive Neurology, Section for Computational Sensomotorics. University Clinics, BCCN, CIN, HIH Tuebingen, [2]Department of Cognitive Neurology, University Clinics, BCCN, CIN Tuebingen, [3]Equal Contribution

Perception of own actions is influenced by visual information and predictions from internal forward models [1]. Integrating these information sources depends critically on whether visual consequences are associated with one's own action (sense of agency) or with changes in the external world unrelated to the action [2] and the accuracy of integrated signals [3]. Attribution of percepts to consequences of own actions depends thus on the

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consistency between internally predicted and actual visual signals. However, is the attribution of agency rather a binary decision ('I did, or did not cause the visual consequences of the action' [4]), or is this process based on a more gradual attribution of the degree of agency? Both alternatives result in different behaviors of causal inference models, which we try to distinguish by model comparison. METHODS. We used a virtual-reality setup to manipulate the consistency between pointing movements and their visual consequences. We investigated the influence of this manipulation on self-action perception. We compared two Bayesian causal inference models to the experimental data, one with a binary latent agency variable [2], and one with a continuous latent agency variable [4]. Here, subject-specific regions for stimulus conditions that maximally differentiate between the two models were identified online using Active Sampling methods [6] to evaluate relative model evidences with a small number of samples. RESULTS/CONCLUSION. Both models correctly predict the data, and specifically empirical agency ratings showing high attribution of agency for small deviations between sensory and predicted feedback. Some participants show signatures of a binary internal representation of agency. In addition, relationships with other inference models [5] are discussed. [1] Wolpert et al.,Science,269,1995. [2] Körding et al.,PLoS ONE,2(9),2007. Shams&Beierholm,TiCS,14,2010. [3] Burge et al.,JVis,8(4),2008. [4] Beck et al.,Jvis,13(9),2013. [5] Marko et al.,JNPhys,108,2012. Ernst,Jvis,7(5),2007. [6] MacKay,NeuralComp,4(4),1992. Paninski,NeuralComp,17(7),2005.

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43.530 **Extracting the global confidence across multiple trials of a visual task** Alan L. F. Lee[1](alanlee.ens@gmail.com), Vincent de Gardelle[2], Pascal Mamassian[1]; [1]Ecole Normale Supérieure & CNRS, [2]Centre d'Economie de la Sorbonne (CNRS) & Paris School of Economics

"Confidence" commonly refers to the judgment of one's performance in general knowledge (memory), motor performance (action), or sensory faculty (perception). However, in most laboratory studies of perceptual confidence, observers make confidence judgments on individual trials or responses, which does not involve the judgment of overall task performance. Here, we are interested in general confidence, the way to measure it, and its characteristics in comparison to single-trial confidence. Observers (N=25) were presented with two Gabor patches simultaneously, and were asked to discriminate their orientations (which Gabor was more tilted) or spatial frequencies (which Gabor had higher frequency). For each observer, the two tasks were randomly assigned as the "global" and the "local" task, respectively. Observers completed the global task in blocks of 40 trials, with each block delivered at a different, calibrated difficulty level. After each block, observers performed 80 trials of the local task. Each local-task trial was immediately followed by a confidence-comparison task, in which observers indicated whether they were more confident 1) in their overall responses across the 40 trials in the global-task block, or 2) in the response they had just given in the current local-task trial. We found that, across all global-task difficulty levels, the proportion of "more-confident-in-local-task" responses monotonically increased with the performance in the local task. Critically, observers adjusted their criterion for the confidence comparison according to the global task difficulty. Finally, we found a reliable confidence bias in favor of the local task. These results were present regardless of the global task, be it over orientation or spatial-frequency. Our results suggest that humans can build a global confidence for overall task performance within a relatively short time, and use it for comparison with the traditional, single-trial confidence. Furthermore, as shown using our "local-vs-global" paradigm, humans tend to be overconfident in the local task.

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43.531 **Action Encoding and Recognition based on Multi-Scale Spatial-Temporal Natural Action Structures** Suxing Liu[1,2,3](suxingliu@gmail.com), Zhiyong Yang[1,2,3]; [1]Brain and Behavior Discovery Institute, [2]James and Jean Culver Vision Discovery Institute , [3]Department of Ophthalmology,Georgia Regents University

Abstract The visual systems of human and animals respond to a range of actions very quickly. This fast and efficient process includes action detection, recognition, and classification. Extensive studies on action recognition have been performed in the areas of machine learning and computer vision. A key issue is to seek efficient encoding units of natural actions. Current global encoding schemes depend heavily on video segmentation while local encoding schemes lack descriptive power. In this work, natural action structures (NAS) were proposed. NAS are multi-size, multi-scale, spatial-temporal concatenations of local features and function as the basic encoding units of actions. Our approach included patch sampling, independent component analysis, Gabor fitting and clustering, feature space mapping, and NAS constructing. Two improvements over an earlier model were made in the approach. First, in the process of sampling a large number of sequences of circular patches at multiple spatial-temporal scales, a machine learning approach was developed to select interest points based on spatial-temporal features. Second, another machine learning approach with cross-validation was developed to select informative NAS for each action. The performance this NAS-based model of action recognition on several widely used datasets was better than that of the start-of-the-art models, including a biologically motivated system. In conclusion, the proposed NAS are a set of good encoding units of natural actions and the NAS-based action recognition scheme provides important insights to natural action understanding. Key Words: Action recognition, Natural Action Structures, Action encoding

43.532 **Modeling response time and accuracy during a visual discrimination stop-signal task** Paul Middlebrooks[1](paul.g.middlebrooks@vanderbilt.edu), Bram Zandbelt[1], Thomas Palmeri[1], Gordon Logan[1]; [1]Dept Psychol, Ctr Integr & Cog Neuro, Vanderbilt Vision Res Ctr., Vanderbilt University

Perceptual discrimination has been explained as the outcome of a stochastic evidence accumulation process. Stop-signal task performance has been explained as the outcome of a race between a GO and a STOP process. We seek to integrate these two modeling frameworks. Macaques and humans performed a visual saccadic choice RT stop-signal task. The choice stimulus was a cyan-magenta checkerboard that appeared above a central fixation spot. Saccade choice was specified by the fraction of cyan or magenta in the checkerboard, varied around discrimination threshold. On 25-40% of trials a visual stop signal replaced the central fixation spot after a variable stop-signal delay. Monkeys were reinforced on no-stop signal trials for correct choices and on stop signal trials for inhibiting the saccade. Behavioral results demonstrate that STOP process duration (stop signal reaction time) did not vary with choice difficulty indicating that perceptual choice and response inhibition function independently (Middlebrooks & Schall 2013 AP&P). Here, we describe an interactive stochastic accumulator model to explain performance of choice and stopping as a function of perceptual choice difficulty. The model assumes one stochastic accumulator for each response alternative plus one accumulator for the stop process (interrupting the response accumulators). Each accumulator has a threshold, an accumulation rate, and a non-decision time. We consider three mechanisms of choice (race, feed-forward inhibition, and lateral inhibition) and three accounts of the manipulation of choice performance (rate, threshold, non-decision time). We fit the various model architectures to the data to determine their account of performance across choice difficulty and stop-signal delays. Each choice mechanism accounted for performance, but best fits used lateral inhibition mechanisms. Variation in accumulation rate provided the best account of variation in choice difficulty. This finding provides a framework in which to interpret patterns of modulation in the neural circuits mediating performance of this task.

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43.533 **Visually-guided interceptive actions performed in virtual environments** David Mann[1](davidlindsaymann@gmail.com), John van der Kamp[1]; [1]Research Institute MOVE Amsterdam, Faculty of Human Movement Sciences, VU University, Amsterdam, The Netherlands

Virtual environments are quickly becoming a pervasive part of everyday life, yet little is known about the visuomotor control of actions performed in these conditions. This is particularly the case for interceptive actions, during which performers interact with objects that are seen, but in virtual environments, are not physically present. We hypothesized that the absence of a targeted object would lead to actions being more influenced by illusory context (and hence the result of different visuomotor processing) when compared to actions performed if the object were present. Twelve participants grasped objects of different lengths that were embedded in a control or illusory background (Ponzo illusion; see Ganel, Tanzer, & Goodale, 2008). Crucially, objects were viewed through a half-silvered mirror in two conditions that simulated (i) a natural environment where the objects sat on a surface in front of participants, and (ii) a virtual environment where the objects appeared to be in an identical position, but were actually images produced by the mirror. Optotrak cameras measured the grip aperture of participants. Results showed that, when grasping objects

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placed against the control background, there was no difference in the scaling of the actions performed in the natural and virtual environments (slope of object size vs. maximum grip aperture; t(11)=-.94, p=.37, two-tailed). In contrast, the illusory background altered the scaling of the grasping actions more in the virtual environment than it did for actions in the natural environment (normalized illusion effect; t(11)=1.92, p=.040, one-tailed). These results suggest that, when compared to natural actions, visually-guided interceptive actions performed in virtual environments are more sensitive to visual illusions. This is consistent with the idea that actions in virtual environments may rely on different (allocentric rather than egocentric) visuomotor processing, and raises doubt about the suitability of virtual environments for testing and training visually-guided actions.

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43.534 **When must one look at the ball in order to be able to catch it?** Joan López-Moliner[1,2](j.lopezmoliner@ub.edu), Eli Brenner[3]; [1]Institute for Brain, Cognition & Behaviour (IR3C), [2]Departament de Psicologia Bàsica, Universitat de Barcelona, Catalonia, [3]VU University, Amsterdam, The Netherlands

In ball games one cannot direct one's gaze at the ball all the time, because one must also judge other aspects of the game, such as other players' positions. We wanted to know whether there are times at which obtaining information about the ball is particularly beneficial. We recently occluded vision at random times and found that people could catch successfully if they saw any part of the balls flight except the very end, when sensory-motor delays make it impossible to use new information. It was even enough to see the thrower propel and release the ball, so it is not even essential to see the ball's flight. Nevertheless, there may be a time that is particularly useful. Here we gave six catchers the chance to choose when they look at the ball. A catcher and a thrower continuously threw a ball back and forth. We recorded their hand movements, the catcher's eye movements, and the ball's path. While the ball was in the air, approaching the catcher, information was provided on a screen as to the peak height of the ball that the catcher had to try to achieve when throwing the ball back to the thrower. This information disappeared just before the catcher caught the ball. Most catchers mainly looked at the screen until the information they needed was provided, and then looked at the ball from then on. However, some mainly first looked at the ball and then at the screen, probably switching once they thought they had enough information to catch the ball. At least two catchers switched between these strategies. The balls' peak heights when thrown back confirm that the catchers saw the information on the screen. Thus there does not appear to be a critical time for seeing the ball.

43.535 **Action distorts perceived duration of sensory consequences** Clare Press[1](c.press@bbk.ac.uk), Eva Berlot[2], Geoff Bird[3], Richard Ivry[4], Richard Cook[5]; [1]Department of Psychological Sciences, Birkbeck, University of London, [2]Division of Psychology and Language Sciences, UCL, [3]MRC Social, Genetic, and Developmental Psychiatry Centre, Institute of Psychiatry, [4]Department of Psychology, UC Berkeley, [5]Department of Psychology, City University London

Perceiving the sensory consequences of action accurately is essential for appropriate interaction with our physical and social environments. Successful interaction with the environment requires perception not only of the nature of our action outcomes (e.g., somatosensation on the fingertips when grasping a cup), but also crucially, the onset and duration of those outcomes. Nevertheless, our perception is rarely veridical. In the present series of experiments, we examine this problem by focusing on how movement influences the perceived duration of sensory outcomes congruent with action. In Experiment 1, participants were required to perform a lifting movement with either their index or middle finger. A short (104 – 296 ms) target vibratory tactile stimulus was presented to the moving or stationary finger, followed by a second reference vibration (200 ms). Participants judged which was of longer duration, and the point of subjective equivalence (PSE) was derived from the resulting psychometric function. In Experiments 2 and 3, participants judged observed avatar finger movements, congruent or incongruent with their own concurrent actions. In all experiments, target events were perceived as longer when the perceived event was congruent with movement. Interestingly, visual effects did not differ as a function of stimulus perspective (first or third person) or spatial location (left / right location of avatar lift relative to participant lift). These results indicate that action modulates the perceived duration of sensory events congruent with action, which may result from predictive mechanisms operating for action selection and error correction. The influence of these biases on tightly time-locked action control and social perception must be considered, given that we may be in contact with grasped objects for less time than we realize and handshakes may be briefer than we believe.

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43.536 **Body and objects representations are associated with similar distortions** Aurelie Saulton[1](aurelie.saulton@tuebingen.mpg.de), Trevor Dodds[1], Heinrich Buelthoff[1,2], Stephan de la Rosa[1]; [1]Max Planck Institute for Biological Cybernetics, Tuebingen, Germany, [2]Korea University, Seoul, Korea

Stored representations of body size and shape as derived from somatosensation (body model) are considered to be critical components of perception and action. It is commonly believed that the body model can be measured using a localization task and be distinguished from other visual representations of the body using a visual template matching task. Specifically, localization tasks have shown distorted hand representations consisting of an overestimation of hand width and an underestimation of finger length [Longo and Haggard, 2010, PNAS,107 (26), 11727-11732]. In contrast, template matching tasks indicate that visual hand representations (body image) do not show such distortions [Longo and Haggard, 2012, Acta Psychologica, 141, 164-168]. We examined the specificity of the localization and visual template matching tasks to measure body related representations. Participants conducted a localization and template matching task with objects (box, post-it, rake) and their own hand. The localization task revealed that all items' dimensions were significantly distorted (all p <.0018) except for the width of the hand and rake. In contrast, the template matching task indicated no significant differences between the estimated and actual item's shape for all items (all p>0.05) except for the box (p<0.01) suggesting that the visual representation of items is almost veridical. Moreover, the performance across these tasks was significantly correlated for the hand and rake (p<.001). Overall, these results show that effects considered to be body-specific, i.e. distortions of the body model, are actually more general than previously thought as they are also observed with objects. Because localizing points on an object is unlikely to be aided by somatosensation, the assessed representations are unlikely to be mainly based on somatosensation but might reflect more general cognitive processes e.g. visual memory. These findings have important implications for the nature of the body image and the body model.

43.537 **Tracking hidden objects with efficient physical prediction** Kevin A Smith[1](k2smith@ucsd.edu), Eyal Dechter[2], Joshua B Tenenbaum[2], Edward Vul[1]; [1]Department of Psychology, UC San Diego, [2]Department of Brain and Cognitive Sciences, MIT

Real-world tracking requires not only maintaining estimates of objects' current locations, but also extrapolating where they will move and using new information to update both state estimates and predictions. We suggest that people accomplish this efficiently by considering a limited number of potential future paths of an object that are updated only when they fail to predict how the world has unfolded. We compare humans to such a rational process model in a task using online judgments of path extrapolation during occlusion. Participants predicted whether a ball bouncing around a bumper table would reach one of two 'goals' first. Participants made continuous predictions by pressing and holding one of two buttons throughout a trial ('no prediction' was allowed). This task was performed on 400 tables, and crucially, many tables contained occlusions that hid the ball as it traveled under them. We compared these predictions to those produced by a model uses a limited number of noisy physical simulations to make predictions, and updates both the current and future states of the world without needing to generate new predictions after each update. This model accounted for whether participants would make any prediction at a given point in time (r=0.89), which goal participants were more likely to choose at each time point (r=0.83), and how often participants changed their predictions on each trial (r=0.79). It also captured how often participants switched predictions when the ball was occluded (r=0.65), suggesting that this model approximates how people store and update representations of the world even when objects are hidden. Finally, this model explained participants' predictions better than an alternate model that assumed people sample predictions from a full posterior predictive distribution. These results suggest that people use computationally efficient physics-based models to track object locations and predict how the world will unfold.

Acknowledgement: BIAL

43.538 **Why is Counting-by-Eye so Difficult? Effects of Spatial Structure and Reduced Luminance** D. Alfred Owens[1](fowens@fandm.edu), Jacob Benedict[1], Carly Campoli[1], Margi Shah[1]; [1]Franklin & Marshall College

It is well known that "20/20 vision" corresponds to a minimum angle of resolution of 1 arcmin, and some observers have much finer resolution with MARs as small as 0.5 arcmin. For much coarser repetitive patterns, however, observers (who are not permitted to use an external pointer) have great difficulty counting elements that are separated by 4 - 9 times limits of visual acuity. Why is Counting-By-Eye (CBE) so difficult? Landolt (1891) asserted that the difficulty results from limitations in oculomotor control, but later research failed to confirm this plausible theory. For example, based on high-resolution recordings of saccadic eye movements, Kowler and Steinman (1977) concluded that perceptual confusion can be more important than oculomotor factors. Building on such earlier work, we conducted three psychophysical experiments to investigate the effects of spatial structure and reduced luminance on CBE. In all experiments, participants counted the elements of repetitive patterns with and without the benefit of an external pointer. Spatial frequencies of the patterns varied from 1 to 8 cy/deg. Results from one experiment showed that CBE performance is significantly better for 1-D (a barcode) than for 2-D targets (tree rings and concentric circles), although subjective ratings of difficulty were opposite actual differences in performance. A subsequent experiment compared the effects of reduced luminance (100 to 1.0 cd/m2) on CBE, with parallel changes in visual acuity (VA) and contrast sensitivity (CS). Surprisingly, CBE accuracy for both 1-D and 2-D patterns showed no effect of reduced luminance, despite the expected (large) decreases in VA and CS. These findings suggest that (1) the ability to count-by-eye is not limited by mechanisms of the foveal resolution and CS; and (2) with further refinement, the CBE method may provide a fast and simple test of the coordination of visual perception and action.

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43.539 **Long-lasting paradoxical effects of attentional-states on visuomotor learning** Joo-Hyun Song[1,2](joo-hyun_song@brown.edu), Patrick Bédard[3]; [1]Department of Cognitive, Linguistic and Psychological Sciences, Brown University, [2]Brown Institute for Brain Sciences, Brown University, [3]Department of Neuroscience, Brown University

Attention is typically viewed as a necessary resource that facilitates cognitive functions. Here, in contrast, we showed that for visuomotor memory retention, attention plays an obligatory role as an internal context rather than as a resource. We recently demonstrated that when visuomotor adaptation initially occurred during a dual-task context requiring divided attention, robust "savings" were paradoxically observed only under divided attention, and not under undivided attention, during recall. This result indicates that divided attention during learning itself does not disrupt new visuomotor memory formation, but does provide a critical context that must be repeated during recall for learning to improve performance. Importantly, the existence of such internal context-dependent "savings" was replicated when the nature of the secondary task or even the modality required for the secondary task changed from adaptation to recall. Here, we examined whether this paradoxical attentional-state is interested in long-term memory. During the adaptation phase, two groups of participants performed a dual-task paradigm: a visuomotor adaptation task (45° CCW rotation) and a concurrent attention demanding rapid serial visual presentation task (RSVP) in which a stream of five inverted or upright 'T's in different colors appeared sequentially. Then, during recall, which occurred one day after the initial learning phase, we manipulated the consistency of attentional states by requiring participants to either perform the RSVP task (RSVP-RSVP) or not (RSVP-No) during recall. We also had a control group who never performed the attentional task (No-No). We found that paradoxically, the RSVP-RSVP group with less available attentional resources improved more at recall than the RSVP-No group but equivalently with the control group. Thus, paradoxical effects of attentional states on memory retrieval lasted at least one day after initial learning. This result suggests that attentional states are integrated into long-term memory, which determines the success of visuomotor memory recall.

Visual memory: Encoding and retrieval

Monday, May 19, 8:30 am - 12:30 pm
Poster Session, Pavilion

43.540 **Intention and Aesthetic Value is not key to large Pictorial Long–Term Memory** Karla Evans[1](karla.evans@york.ac.uk), Alan Baddeley[1]; [1]The University of York

Studies of pictorial long-term memory have shown that humans have an astonishing ability to remember with high fidelity previously viewed scenes (Konkle et al., 2010) with robust memory for visual detail (Castelhano & Henderson, 2005). How to explain this massive pictorial long-term memory? We tested the robustness of scene memory under intentional and incidental encoding with 100 exemplars from each of four categories (cityscape, indoor scenes, waterscapes & landscapes) and examined if aesthetic valence affects memorability of scenes. We randomly assigned observers to two conditions, either intentional or incidental memory group. Both groups followed the same experimental procedure except that only the intentional group was aware their memory was going to be tested. In the first phase observers saw 200 scenes, one at a time, each for 3 seconds and were asked to rate the pleasantness of the scene on a 4-point scale. In the phase that followed, they were shown another 200 images, half of which were seen in the study phase and randomly intermixed with new images not previously viewed, and asked to respond old or new to each image. During the third phase observers rated again the pleasantness of the last 200 scenes of which half were seen during the first study phase. Observers unaware of the memory test performed at the same level as observers intentionally memorizing the scenes (d'=1.85 for both groups) with a significant correlation in memorability of images across the two conditions (.27 at $p<0.01$). Perceived pleasantness of scenes had no affect on memory performance in either of the conditions even though pleasantness rating increased with familiarity ($p<0.02$). High fidelity encoding into pictorial long-term memory does not seem to require any intent and the memorability of image is intrinsic to the image, reproducible under any encoding condition and independent from it's aesthetic valence.

43.541 **Briefly flashed scenes can be stored in long-term memory** Michèle Fabre-Thorpe[1,2](michele.fabre-thorpe@cerco.ups-tlse.fr), Arnaud Delorme[1,2], Marlène Poncet[1,2]; [1]Université de Toulouse UPS Centre de Recherche Cerveau et Cognition France, [2]CNRS CerCo Toulouse, France

The capacity of human memory is very impressive. Previous reports have shown that when asked to memorize images, participants can recognize several thousands of visual objects in great details even with a single viewing of a few seconds per image. In this experiment, we tested recognition performance for natural scenes that participants saw for only 20ms in an unrelated task. A group of participants performed an animal/non-animal categorization task for 15 days on the same 200 images. One week later, this trained group and another untrained group of participants saw the 200 images once (for the first time for the untrained group) and were tested 10 minutes later in an unexpected recognition task along with EEG recordings. In this task, 400 images (200 previously viewed and 200 novel images) were flashed one at a time and participants were asked to lift their finger from a pad whenever they thought they had already seen the image (go/no-go paradigm). Compared to previous reports of excellent recognition performance with only single presentations of a few seconds, untrained participants were able to recognize only 59% of the 200 images they had seen few minutes before. On the other hand, trained participants, who had seen the images 21 times (20ms each), could correctly recognize 87% of them. EEG recordings confirmed these behavioral results. As early as 230ms after stimulus onset, a significant ERP difference between familiar and new images was observed for the trained but not for the untrained group. Consistent with previous literature, for both the trained and the untrained group, we also found an automatic processing of visual object categories, demonstrated by an ERP difference between animal and non-animal images around 170ms after stimulus onset. These results show that briefly flashed unmasked scenes can be incidentally stored in long-term memory when repeated.

43.542 **If at first you don't retrieve, try, try again: The role of retrieval failures in visual working memory** Daryl Fougnie[1](daryl-fougnie@gmail.com), Timothy F. Brady[1], George A. Alvarez[1]; [1]Department of Psychology, Harvard University

The severely limited capacity of visual working memory is thought to result from a fixed storage capacity, rather than limitations at encoding or retrieval. Thus, most investigations of working memory have focused on understanding the storage system—its capacity, its flexibility, and the units over which it operates. Little work has investigated how items are retrieved from working memory, with retrieval typically seen as straightforward, since items in working memory are actively maintained and thus directly accessible. Here we show that working memory is limited not only by storage capacity but also by failures to retrieve successfully maintained items. Specifically, we asked participants to remember the colors of five briefly presented circles. Participants were first asked to report a randomly probed item's color by performing a continuous report judgment. Many responses deviated from the true color, reflecting limitations on memory that are typically interpreted as showing that little or no information was maintained about the probed item. To determine whether participants might know information about the item despite reporting an incorrect value, we asked participants about the probed item a second time: Participants were given two color choices, one correct and the other a foil, and had to choose the correct color. To avoid anchoring, the choices were equidistant in color from the participants' first response. If everything a participant knows about an item is captured by the first response, participants should be at chance on this judgment. However, participants chose correctly at greater than chance rates (63%, p<.001) even when the first response was highly inaccurate (>90° error) (61%, p<.001). These results suggest that typical paradigms underestimate how many items participants can maintain in memory. In addition, they demonstrate an important role for retrieval in working memory, sometimes items that are successfully stored are not successfully reported.

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43.543 **Semantic bias in visual working memory** Farahnaz Ahmed Wick[1](farahnaz@gmail.com), Lucia Saura[1], Chia-Chien Wu[1], Marc Pomplun[1]; [1]University of Massachusetts Boston

This study investigated whether and how the semantic relationships among individual objects from a scene context are bound to visual short term memory (VSTM). Previous studies (Hwang, Wang & Pomplun, 2011) indicate that our strategies for memorizing objects in naturalistic scenes can be predicted by the semantic relationships between objects in that scene. That is, we tend to make saccades to objects that are most semantically related to the object in the current fixation. Why do such biases exist? One possibility is that consecutive inspection of semantically similar objects facilitates object memorization. We tested this hypothesis using a rapid serial presentation paradigm in which a series of eight object images were shown for 250 ms each. Each image in the series consisted of a single grayscale object against a white background. Subsequently, participants saw another image and indicated whether it had been in the series. In six experiments, we varied the object sets (either randomly chosen or taken from a specific context such as airport, park, or bedroom), the target objects for negative responses (objects from same or different contexts, or even of the same type as an object in the set), and their order of presentation (consecutive objects of high versus low semantic relationship). Recall rates were significantly better when objects were from the same context, and when they were ordered to maximize the semantic similarity of consecutive objects. Generally, these recall rates seemed to be governed by object types and semantics rather than by the specific visual features of individual objects. These results demonstrate that object representations are episodically organized in VSTM according to scene context.

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43.544 **Attentional inhibition has affective consequences for visual stimuli represented in short- and long-term memory** David De Vito[1](ddevito@uoguelph.ca), Anne E. Ferrey[1], Katherine McArthur[1], Mark J. Fenske[1]; [1]Department of Psychology, University of Guelph

Ratings of previously ignored visual stimuli reveal affective devaluation of such items when compared to ratings of novel items or the targets of attention. Growing evidence suggests this effect may reflect negative affective associations elicited by attentional inhibition of visual distractors. Here we investigate whether such 'inhibitory devaluation' is limited to situations involving visual-spatial selection of environmental stimuli (i.e., external attention) or extends to the selection of competing visual representations held solely in memory (i.e., internal attention). A two-item target-localization task in Experiment 1 utilized a delayed target-category cue ('circles' or 'squares') to ensure attentional selection occurred from the contents of working memory. An n-back task in Experiment 2 was used to examine the affective consequences of rejecting continually-updated visual representations when items held in memory did not match the corresponding visual display. And a Think/No-think paradigm employed in Experiment 3 was designed to explore the affective consequences of actively suppressing longer-term visual object memories. Across this relatively-wide range of memory-based selection tasks, the ignored/rejected/suppressed visual patterns consistently received more negative affective ratings than target items. Our results are consistent with prior suggestions that similar mechanisms are involved in the attentional selection of environmental stimuli and the selection of internally-maintained information that occurs even in the absence of external sensory stimulation. The similarity in these mechanisms appears to extend not only to processes of attentional selection, per se, but also to their affective consequences.

Acknowledgement: NSERC

43.545 **Attention is Necessary for Iconic Memory** Muge Erol[1](erolm712@newschool.edu), Arien Mack[1], John Bert[1]; [1]Psychology Department, New School for Social Research

Does iconic memory require attention? Pinto et al. (2013) suggest it does not. Persuh et al. (2012) suggest it does. The study we present extends and confirms the conclusion that iconic memory requires attention. Trial by trial, 30 observers were asked to report either one of the 2 rows in a 3x2 letter matrix located at fixation or whether there was an odd circle among 4 circles located at the corners of a notional square around the matrix. Arrays were visible for 250 ms followed by the cue indicating what to report. Attention to the matrix was manipulated in two ways: 1) By adjusting the perceptual load of the circle task; easy or hard, (within participant manipulation), 2) By changing the probabilities of whether the circle or matrix task was performed on a given trial, (between participant manipulation). The ratios of circle to matrix trials were 40/60, 60/40, 80/20. Ten subjects were tested in each ratio condition. An additional 30 observers were tested with the same procedure but gave whole matrix reports. We predicted that if attention is necessary for iconic memory the following should be true. The number of matrix items reported should be fewer when the circle task is hard and should decrease as the probability of having to report the matrix decreased, because in both cases attention should be drawn away from the matrix. Both predictions were confirmed. Performance on the matrix task decreased as a function of the difficulty of the circle task (F(2,108)= 38.52, p=.00, np2=.832) and as the probability of matrix reports decreased (F(4,108)= 28.45, p=.00, np2=.513). We also found the predicted significant advantage of partial over whole reports (F(2,108)= 9.99, p=.00, np2 =.156) indicating that in fact we were manipulating iconic memory. The results strongly support the conclusion that iconic memory requires attention.

43.546 **Pupil Response Predicts Memory Strength in a Visual Short-term Memory Task** Sylvia Guillory[1], Zsuzsa Kaldy[1], Mohinish Shukla[1], Marc Pomplun[1]; [1]University of Massachusetts Boston

Introduction: Previous research has suggested that changes in pupil diameter reflect mental effort in verbal short-term memory tasks, dilating with increases in memory load and constricting during recall (Kahneman & Beatty, 1966, Science). We sought to describe the relationship between mental effort and performance in a visual short-term memory task using pupillometry. We predicted that greater pupil dilation (more mental effort) during encoding and/or maintenance correlates with higher performance. Method: Participants performed an object recognition task, where on each trial two computer-generated scenes were presented to the left and right of central fixation. Each scene contained six target objects. A visual cue prior to the presentation of the scene instructed participants which scene to attend to, allowing them to search the scene for the objects. Attention was controlled by varying cue reliability (100%, 75%, and 50%). After a three second delay, participants were probed about a single object, indicating whether it was present or not in the scene. For each response, participants also rated their confidence level. Eye gaze data and pupil diameter was collected using a Tobii T120 eye tracker. Results: Performance (correct recall) was greater for the 100% reliable cue condition compared to the 75% and 50% conditions and participants reported greater confidence in their responses in the 100% condition. The magnitude of pupil dilation during the delay period tended to be greater for correct than incorrect responses. Conclusion: These findings provide further support that pupillometry is a powerful and sensitive index of mental effort in visual memory tasks. Greater effort during memory maintenance predicts better performance in visual short-term memory tasks.

43.547 **The first four seconds: an assessment of post-stimulus processing in visual short-term memories** Jane Jacob[1,3](jjacob9@uh.edu), Bruno Breitmeyer[1,2], Melissa Trevino[1]; [1]Department of Psychology, University of Houston, [2]Center for Neuro-Engineering and Cognitive Science, University of Houston , [3]Department of Psychology, University of Westminster

Priming and comparison tasks were used to assess the time course of iconic and post-iconic processing in visual short-term memory (VSTM) for form and/or color features. A prime preceded a probe at varying stimulus onset asynchronies (SOAs); observers reported the probe's form or color feature in the priming task, and whether or not the probe matched the prime in the comparison task. Three SOA ranges were used: short (0-1920 ms); long (0-4160 ms), and another long (253-3950 ms). Using the short range, Jacob, Breitmeyer & Treviño (2013) obtained evidence for three stages of VSTM processing: iconic visible persistence (0-130 ms), informational persistence (130-700 ms), and visual working memory (700-2000 ms). In the present study, both the 0-1920 ms and 0-4160 ms ranges yielded priming effects that rapidly declined after peaking at 40ms and 133ms, respectively; no significant effects occurred beyond a 700-ms SOA. In contrast, priming effects in the 253-3950 ms range lasted twice as long, ending at the 1500-ms SOA, suggesting that participants may be strategically retaining prime information for longer intervals in the sensorimotor system when SOAs are sampled at long SOA ranges excluding the lowest SOAs. Additionally, comparison effects in both long-range SOAs yielded evidence for a fourth VSTM stage. Our results indicate that information is processed differently at different post-stimulus intervals due to variations 1) of the processing stages in VSTM and (2) of cognitive strategies induced by variations of the SOA range at which VSTM processing is assessed.

43.548 **Assessment of Maintenance and Consolidation in Visual Short-Term Memories** Melissa Trevino[1](mtrevino@uh.edu), Bruno Breitmeyer[1], Jane Jacob[1]; [1]University of Houston

Prior studies of information transfer rates from brief iconic to durable post-iconic levels of processing differ significantly. Estimates range from roughly 10 ms/letter to 50 ms/letter consolidation rate, indicating that initial readout of information from iconic to post-iconic levels of processing may not be identical to subsequent processes of consolidation of information in visual working memory. Moreover, Woodman and Vogel (2005) report that concurrent WM maintenance does not affect the efficiency of information consolidation into WM. To clarify, we examined how maintaining variable-load color information in working-memory interacted with the information transfer from iconic to post-iconic levels. Using a dual-task paradigm, observers maintained color information, from a 300-ms display consisting of one, two or else three disks, in WM while concurrently reading out information from iconic storage of a briefly presented (10 ms) six-letter array. A random noise mask followed the letter array at interstimulus intervals from 0 to 100 ms. A probe display was then presented, in which on half the trials, the probe was a color disc, and on the other half, a single letter. Observers had to indicate whether the probe was or was not shown in the prior respective color or letter display. Results revealed concurrent readout of letters worsened WM performance, as load increased. Overall, iconic readout rose steeply over the early ISIs ranging from 0 to 60 ms, followed by a plateau from 60 to 100 ms. When concurrent WM maintenance was required the rapid rate of iconic readout rate from 0 to 60 ms decreased as WM load increases, indicating that the initial rate of readout from iconic to post-iconic levels of processing is slowed down as more information is maintained in WM. In contrast, the later, ISIs from 60 to 100 ms of iconic readout did not vary with WM load.

43.549 **Factors at Encoding and Retrieval Affect Color Precision in Visual Working Memory** Michael Patterson[1](mdpatterson@ntu.edu.sg), Miao Qin Sim[1]; [1]Division of Psychology, Nanyang Technological University

Three experiments investigated factors affecting color precision with a fixed object load in visual working memory. The first experiment investigated color similarity and grouping across objects. Six colored-dots were presented every trial. In half the trials, three dots were the same color, and three dots were unique colors. In other trials all dots were unique colors. After a 500ms delay, participants selected a color from a wheel for a single probed dot. Color recall was significantly more accurate when the probed dot was identically-colored than uniquely-colored. The results could be due to the decrease in total quantity of colors to-be-remembered or due to the limited color range in trials with fewer colors. Experiment 2 tested the limited range hypothesis by presenting either a narrow or wide color range using three dots per trial. After a 1000ms delay, color memory for a single probed dot was significantly more accurate for a narrow than wide range of colors. Standard deviations and patterns of responses were comparable between both conditions, indicating that results were not due to guessing. However, in the narrow range condition, the test color wheel contained unprobed colors. These unprobed colors may have either allowed participants to rule out some color wheel options, or aided the recovery of the probed color by giving context. Experiment 3 used identical stimuli to Experiment 2 with participants choosing from six carefully selected options at response instead a color wheel. Probed colors were recalled much more accurately when unprobed colors were given as options than when decoys were all from the same color group (e.g. shades of blue). The results indicate that participants can use context at the recall phase to aid selection of the correct color, and show both encoding and retrieval manipulations influence color precision in working memory.

43.550 **Revaluating the Visual Short-Term Memory Benefit for 3-D Stimuli** Sarah R. Zohar [1](sar.zohar@gmail.com), Laurie M. Wilcox[1]; [1]Department of Psychology, Centre for Vision Research, York University, Toronto, Canada

Given the 3-D nature of the visual environment, it is surprising that the majority of research in visual short-term memory (VSTM) has focussed on 2-D object properties. Experiments that have assessed effects of 3-D location on VSTM used sequentially presented depth planes (Xu & Nakayama, 2007, Journal of Experimental Psychology, 136, 653-662). Due to vergence eye movements, these sequential arrays were effectively presented at zero disparity. Here we use a different paradigm to evaluate the effect of distributing elements in depth on VSTM. Oriented line segments (square brackets) served as the visual stimulus to be retained in VSTM. We used a letter recall task to keep observers from rehearsing a cognitive descriptor of bracket orientation (e.g. up, down, left, right). On each trial, observers viewed a series of (3-4) letters (750ms) followed by an array of square brackets (1000ms) presented at two randomly selected orientations on each trial. In the test phase another set of letters appeared and observers indicated if they were the same or different from the first (50% of trials one letter was different). Two square brackets then appeared and again observers indicated same or different (50% of trials one item was different). Reaction time was measured for each task. There were four stimulus conditions: i) zero disparity (single plane) ii) zero disparity half density iii) two disparity-defined planes with oriented brackets randomly distributed iv) two disparity-defined planes each consisting of one orientation. Our proportion correct and d' measures show that VSTM does benefit from simultaneous distribution of elements across depth planes. However, the advantage is not due to increased sensitivity in the 3-D offset condition, but to reduced sensitivity in the single plane condition. We conclude that location binding is not the critical factor; the addition of multiple planes helps isolate features of interest, permitting efficient storage.

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43.551 **Facilitating 6-month-old infants' visual short-term memory for multiple-item arrays** Shipra Kanjlia[1,2](skanjli1@jhu.edu), Steven J. Luck[2,3], Lisa M. Oakes[2,3]; [1]Department of Psychological and Brain Sciences, Johns Hopkins University, [2]Center for Mind and Brain, University of California, Davis, [3]Department of Psychology, University of California, Davis

Visual short-term memory (VSTM) abilities undergo rapid development in infancy. Whereas 6-month-old infants detect changes only in arrays containing one item, 8-month-old infants detect changes in arrays of 2 to 3 items (Oakes et al., 2006, 2013). Moreover, 6-month-old infants evidently fail to encode any information from multi-item arrays into VSTM (Oakes et al., 2006, 2009). The mechanism of this development between 6 and 8 months remains elusive. Here we asked whether 6-month-old infants' failure to encode any information from multi-item arrays is related to difficulties with simultaneously individuating multiple items. We tested twenty-two 6-month-old infants in a one-shot change detection procedure. On each trial, a sample array of two colored items is presented briefly (500 ms), followed by a retention period (300 ms) and then a test array consisting of two colored items (1917 ms). One test item is unchanged from the sample to test array and the other item is changed to a new color. Critically, we facilitated individuation of the two items in the sample array by staggering their onset: one item appeared alone for 100 ms, then the other item appeared and both items were visible for 400 ms, and then the first item disappeared, leaving the remaining item visible alone for 100 ms. We recorded infants' eye positions using an infrared eye tracker. Infants looked significantly longer at the changed test item than at the unchanged test item, $t(21) = 4.17$, $p < 0.0005$, $d = 1.82$. In contrast, we previously found that 6-month-old infants looked equally at the changed and unchanged test items when the sample items appeared simultaneously (Oakes et al., 2013). Thus, a staggered onset—which presumably helps

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infants individuate the to-be-encoded objects—leads to improved VSTM performance in 6-month-old infants, suggesting that the ability to individuate multiple items is an integral component of VSTM development.

43.552 **The Use of Relations and Prototypes in a Spatial Memory Task Depends on Timing** David Landy[1](dlandy@indiana.edu), L. Elizabeth Crawford[2], Amanda N. Presson[2]; [1]Psychological and Brain Sciences, Indiana University, [2]Psychology, University of Richmond

People remembering the spatial location of briefly displayed objects use categorical information about scenes to reduce errors in judgment (Huttenlocher, Hedges, & Duncan, 1991). People are thought to adjust inexact memory for the object's location with information about the region (e.g., "right half of the screen") in which it appeared, leading estimates to be biased toward category prototypes. The categorical organization used is thought to be consistent across people and various task manipulations. In contrast, the current study suggests that category structure may change as a function of memory delay. Undergraduates remembered the location of single dots in a large rectangular display for either 300ms or 3000ms. Then a centrally located mouse pointer appeared, and participants moved it to indicate their remembered location. Observed bias was large at the longer delay. Responses tended to be biased outward from the center across much of the range and inward near the outside of the screen. In contrast to previous work (Huttenlocher et al., 1991), estimates for short-delay trials were biased outward across most of the range, decreasing only due to truncation at the screen edge. Though responses at short delays showed a clear systematic deviation from the stimulus location, the form of the bias is not compatible with a category adjustment model that assumes a category prototype on the screen. At short delays, the bias appears to be relational: dots were categorized as left or right, but not drawn to a central, prototypic value. In contrast to prior findings, these results indicate that manipulations of temporal delay (and thus memory uncertainty) lead people to take advantage of different types of categorical information.

43.553 **Mapping the spatial distribution of short-term memory representations for visual motion** Adam C Riggall[1](riggall@wisc.edu), Bradley R Postle[1,2]; [1]Department of Psychology, University of Wisconsin-Madison, [2]Department of Psychiatry, University of Wisconsin-Madison

We have recently demonstrated the successful time-point-by-time-point decoding, with multivoxel pattern classification, of remembered directions of motion during a short-term delayed-recognition task (Riggall & Postle, 2012). Importantly, this item-level decoding was only possible within medial and lateral occipital cortex ROIs and not in frontal and parietal ROIs that contain robust, elevated delay-period signal. Here, we address the seemingly paradoxical fact that, in the same data, 'importance maps' from whole-brain results, for which decoding performance was slightly better than in any individual ROIs, contained a number of important voxels located in frontal and parietal regions. We used an iterative approach to determine the optimal set of whole-brain voxels necessary for maximal classification performance. Starting with the single-most predictive voxel, we iteratively added the next most predictive voxel until maximal classification performance was achieved ('build-up model'). We complemented this with the reverse process, starting with the full set of feature-selected voxels and iteratively removing the least informative voxels ('knock-out model'). These two approaches provided generally comparable results. Voxels outside of the medial and lateral occipital cortex were added late in the build-up model (always within the last 33% of voxels added) or dropped early in the knock-out model (within the first 40% of voxels dropped). Large-scale simulations of the data, varying the relative signal-to-noise ratio and correlations between patterns in different regions and repeating the build-up and knock-out classification analyses, suggest that such results are consistent with small contributions from non-occipital regions, but only when they are correlated with posterior regions. These results suggest that, whereas frontal and parietal regions may participate in broadly distributed representations of trial-specific information, these regions cannot be construed as storing 'independent' mnemonic representations.

Scene perception: Categorization and memory

Monday, May 19, 8:30 am - 12:30 pm
Poster Session, Pavilion

43.554 **The importance of visual features in rapid scene categorization: Evidence from repetition blindness.** Martin J. Goldzieher[1](mgol6527@uni.sydney.edu.au), Irina M. Harris[1]; [1]School of Psychology, University of Sydney

Previous research has shown that the gist of a visual scene can be understood in as little as 100ms (Potter, 1975; Oliva & Torralba, 2001). Here we used Repetition Blindness (RB) to investigate what underlies this rapid processing. RB is the failure to report the second instance of a repeated item in a rapid serial visual stream (RSVP) of information. It is thought to reflect the repeated activation of a memory representation ("type"), but a failure to individuate the repeated items into distinct visual episodes. We sought to determine what aspects of a stimulus contribute to type activation, by varying the level of similarity (visual feature vs categorical) between critical items. Participants viewed RSVP streams containing either two or three scene images preceded and followed by masks. We manipulated the relationship between the first and last scenes, such that they were: 1) identical repeated images, 2) mirror-reversed versions of the same image, 3) different members of the same category (e.g., two different beaches), or 4) scenes from different categories (non-repeats). Across different experiments, we measured participants' accuracy in reporting the scenes or their sensitivity to detect repetitions, using a range of presentation rates (106ms – 153ms/item). We consistently failed to find RB for scenes. In general, participants were more accurate in reporting repeated scenes compared to non-repeats (i.e., showed repetition advantage), and showed better sensitivity to detect repetitions of the same scene. This was true for both identical and mirror-reversed repeated scenes, though the advantage for mirror-reversed scenes was only apparent with longer exposure durations. In contrast, category repeats were no different from non-repeated scenes. These results suggest that early processing of scenes relies on the visual features present in the image, rather than higher-level categorical information.

Acknowledgement: Australian Postgraduate Award

43.555 **Spatial Frequency in Detection of Grayscale Pictures in RSVP** Carl Erick Hagmann[1](chagmann@mit.edu), Mary C. Potter[1]; [1]Brain & Cognitive Sciences, Massachusetts Institute of Technology

Previous experiments have shown that conceptual information can be readily extracted from rapid serial visual presentations (RSVPs) of pictures (Potter, 1976; Potter et al., in press). Bar et al. (2006) hypothesized that a coarse, rapid magnocellular pathway transmitting low spatial frequencies (LSFs) to the orbitofrontal cortex provides possible identities for objects that are fed back to lower levels in the visual system, enabling such rapid perception. To test this hypothesis viewers detected named targets (e.g., smiling couple, harbor) in RSVP sequences of six grayscale pictures that were either unfiltered or filtered to provide only low spatial frequencies (LSFs). The pictures were new to the participants and were never repeated. The six pictures in each trial were presented for 13, 27, 53, or 80 ms each. When the target was named before the sequence, unfiltered pictures were detected more accurately than LSF pictures but both gave above-chance detection results at all durations. When the name was given afterward only the unfiltered pictures were detected above chance (except at 80 ms), suggesting that the LSF image was not able to activate the relevant concept without advance target information. Overall, the results raise critical questions about Bar et al.'s magnocellular feedback hypothesis, suggesting instead that feedforward processing (e.g., Serre et al., 2007) can be sufficient to activate conceptual representations without cortical feedback or prior knowledge of the target.

Acknowledgement: MH47432

43.556 **Perception of real-world scenes at multiple spatial scales** Caitlin Mullin[1](caitlin.mullin@ppw.kuleuven.be), Nicola Van Rijsbergen[2], Philippe Schyns [2], Johan Wagemans[1]; [1]Laboratory of Experimental Psychology, University of Leuven (KU Leuven), Belgium, [2]Institute of Neuroscience and Psychology, University of Glasgow, UK

Scenes contain a wealth of information that can be selected and processed differently depending on the requirements of the observer. While some scenes are categorized by their global spatial layout (e.g. corridor) and therefore defined by their boundary-related parts, others are categorized by local diagnostic objects (e.g. bed in a bedroom) and hence are defined by their content-related parts. Additionally, the spatial scale of information required to identify and categorize visual stimuli has been shown to change (Collin & McMullen, 2005, Percept Psychophys 6: 354) depending on the level of classification (subordinate, basic, superordinate). Several studies that have attempted to characterize scenes based on hierarchy of components and spatial scale often cue the participant to respond to one of these specific levels, and therefore bias the perception of the scene overall. We conducted an extensive investigation using an uncued, and therefore unbiased, task in which participants freely described scenes at multiple spatial scales. Independent observers subsequently rated the responses for accuracy on a predetermined list of attributes shown to tap into hierarchical categorization (similar to Fei-Fei et al., 2007, J Vis 7:1). Data were analyzed to identify the scale of interest, which is described as the largest transition in accuracy across the spatial scales. Preliminary results reveal that the scale of interest follows a hierarchical progression, such that superordinate categories of scene and object are more accurately described at lower spatial scales than basic or subordinate categories. However, no significant difference was observed between the later two. In addition, participant's perceived responses were compared to the ground-truth for several attribute categories revealing a bias to report low frequency images as outdoor. Results are discussed with reference to perceptual differences in natural/urban environments, sensory and semantic perception, and the taxonomy of scene categorization.

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43.557 **Sensitivity to spatial ensemble statistics predicts rapid scene perception ability** Anna Shafer-Skelton[1](annashaferskelton@gmail.com), Timothy F. Brady[1], George A. Alvarez[1]; [1]Department of Psychology, Harvard University

Many influential models of scene perception treat objects as the basic unit of scene recognition. However, there is evidence that global properties of an image can drive scene perception before any objects can be identified (e.g., Greene & Oliva, 2009), and computational models suggest this ability could be explained by sensitivity to global patterns across an image (e.g., Oliva & Torralba, 2001). To examine this possibility more directly, we asked whether there is a link between how proficient observers are at representing global patterns (spatial ensemble statistics) and their ability to perform rapid scene recognition. To measure ensemble perception, participants performed a change-detection task in which a grid of Gabors changed orientation, with some changes altering the global pattern of a display (ensemble-different) and others leaving the global pattern the same (ensemble-same; Alvarez & Oliva, 2009). To the extent that participants are sensitive to the ensemble, it should be easier to notice changes on ensemble-different trials than ensemble-same trials (ensemble-benefit). To measure rapid scene recognition, we briefly presented objects with consistent backgrounds vs. inconsistent scene backgrounds, and observers had to report the identity of the object (Davenport and Potter, 2004). To the extent that participants are better at rapid scene recognition, they should have higher accuracy for consistent backgrounds than inconsistent backgrounds (context-benefit). By comparing relative performance scores (ensemble-benefit versus context-benefit), we controlled for factors such as motivation and general object processing skill in accessing ensemble and scene processing abilities. We found a significant correlation between ensemble processing scores and rapid scene perception (N=50; r=0.46; p=0.001): Observers who made the best use of ensemble representations were also most influenced by scene backgrounds in an object recognition task. These results suggest that spatial ensemble representations may underlie rapid scene recognition.

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43.558 **Scene syntactic priming boosts lexical access.** Melissa Vo[1](mlvo@search.bwh.harvard.edu), Jeremy Wolfe[1]; [1]Harvard Medical School, BWH

While there is no doubt that word-specific and picture-specific operations contribute to language and scene understanding, respectively, the two domains are not completely separate. For example, words can prime object recognition and vice versa. Here we ask if conceptual knowledge of the typical locations of objects in scenes ("scene syntax") affects perceptual and lexical decisions. In two experiments, we presented a preview of an indoor-scene (500ms) followed by a location cue (500ms). Then either an image of an object (Exp.1) or a string of letters (Exp.2) appeared at the pre-cued location within the scene. Observers had to decide as quickly as possible, whether the object was visually distorted (Exp.1) or whether the letter string formed an English word (Exp.2). Objects/words could either be congruent with location in the scene (soap on sink), semantically incongruent (egg on sink), syntactically incongruent (soap on towel rack – that is, the soap is appropriately semantically associated with the sink but it is in the wrong location, relative to the sink), or doubly-incongruent (egg on towel rack). In Exp.1, though the task involved only the object's perceptual characteristics, semantic incongruity impeded performance compared to fully consistent control scenes. Syntactic incongruity didn't impede performance. In contrast, in Exp.2, lexical decisions were impeded by both semantic and syntactic incongruity. That is, observers are slower to categorize "EGG" as a word in a semantically incongruent bathroom scene than in a kitchen and slower to accept "SOAP" as a word if presented in a syntactically incongruent position in that bathroom, compared to an appropriate location on top of the sink. We therefore argue that lexical processing is primed not only by semantic associations with scenes or objects, but also by syntactic understanding of the likely position of an object in a scene.

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43.560 **Reduced ERP amplitudes for animal stimuli in the absence of conscious awareness** Weina Zhu[1,2,3](zhuweina_xm@sina.com), Jan Drewes[4], Karl Gegenfurtner[2]; [1]School of Information Science, Yunnan University, China, [2]Department of Psychology, Giessen University, Germany, [3]Kunming Institute of Zoology, Chinese Acad. of Science, China, [4]Center for Mind/Brain Sciences (CIMeC), Trento University, Italy

Humans can rapidly and easily extract categorical information from complex natural scenes (Thorpe, Fize et al. 1996). It is unclear whether rapid object recognition is limited to conscious perception. We investigated this by recording event-related potentials (ERPs) in both conscious and unconscious conditions, while using a continuous flash suppression (CFS) paradigm to suppress the target images during the experiment (Tsuchiya and Koch 2005). We equated the histograms of the images to minimize potential low-level confounds in our study. Image contrast was adaptively controlled to ensure 50% of the images were seen during CFS. After each trial, subjects were asked whether they saw any image. Subsequently, they decided/guessed the target category (animal or not). Trials were then separated into seen and unseen. In experiment 1, accuracy was 77% vs. 49% for seen and unseen, confirming subjects were truly unaware of "unseen" images. We compared the ERP waveforms in two time windows: 150-200ms and 250-300ms. The results showed animals induced higher amplitude than non-animals in seen trials; but smaller amplitudes than non-animal images in the unseen trials (150-200ms: $F(1, 15) = 31.8$, $p < 0.001$; 250-300ms: $F(1, 15) = 12.8$, $p < 0.001$). As a control experiment, we replaced the generic non-animal images with vehicle images, now asking subjects to discriminate between animals and vehicles. Similar to experiment 1, animal images induced bigger amplitudes than vehicle images on seen trials, but smaller amplitudes in the unseen trials (150-200ms: $p < 0.001$; 250-300ms: $p < 0.001$). Under CFS conditions, unlike the unseen stimuli, the seen animal stimuli produced bigger amplitudes than non-animals, opposite to previous reports without masking (Thorpe, Fize et al. 1996). Our results indicate the brain responds in a special way to animal stimuli even in unawareness, and the rapid processing of animal images might differ between conscious and unconscious conditions.

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43.561 **Perceiving the global: The role of surface texture consistency in object and background perception** Matthew X. Lowe[1](matthew.lowe@mail.utoronto.ca), Jonathan S. Cant[1]; [1]Psychology Department, University of Toronto Scarborough

Navon (1977) demonstrated a global precedence effect in shape processing (faster judgments of local shape when local and global shapes are congruent, but not vice versa), suggesting the importance of global spatial cues (i.e. shape) in scene and object processing. Investigations of scene processing using fMRI are consistent with this, as they have demonstrated that the parahippocampal place area (PPA) represents scenes by processing global spatial properties (Epstein et al., 2003). Recent fMRI experiments show that PPA also represents scenes by processing non-spatial cues such as texture (Cant & Goodale, 2011). If texture is important in global scene perception, then in addition to the well-documented global precedence for shape, we should also observe a global precedence effect in texture processing (faster judgments of local texture when local and global textures are congruent). We investigated this in two experiments using modified Navon stimuli and cued participants to make speeded judgments of shape (star vs. heart) and texture (paint vs. rock) at both global and local levels. In Experiment 1, we integrated local and global shape and texture within a single Navon

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stimulus (all features were contained within a global outline contour), and observed a global precedence effect for both shape and texture. Surprisingly, we also observed a local precedence effect for texture (faster judgments of global texture when local and global textures were congruent). In Experiment 2, local and global shape remained integrated, but we separated local and global texture into foreground and background elements, respectively. We replicated global precedence effects for shape and texture, but the local precedence effect for texture was eliminated. These results demonstrate a global-processing bias for both shape and texture, and suggest that the ways in which visual features are integrated may play an important role in processing foreground (object) and background elements in scenes.

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43.562 **Interactions between space-based and category-based attention in the ventral and dorsal visual system during real-world visual search**

Katharina N. Seidl-Rathkopf[1,2](kseidl@princeton.edu), Jiye G. Kim[1], Marius V. Peelen[3], Sabine Kastner[1,2]; [1]Princeton Neuroscience Institute, Princeton University, [2]Psychology Department, Princeton University, [3]Center for Mind/Brain Sciences, University of Trento

Humans are extremely efficient at detecting object categories (e.g., people) in briefly presented natural scenes. Recent work investigating the neural mechanisms underlying this ability suggests that rapid object category detection is supported by the implementation of top-down category-based attention signals that enable efficient target processing through the pre-activation of category-selective neurons in object-selective occipito-temporal cortex (OSC). A separate line of research in our lab has recently demonstrated that topographically organized regions in the parietal cortex (e.g., posterior IPS areas) that are involved in the generation of space-based attention signals also demonstrate object-selective responses. Here we used fMRI with a MVPA approach to investigate the relationship between object category-specific and space-based attention signals in OSC and IPS areas. Participants were briefly presented with natural scenes to both the left and right of a central fixation cross. On separate runs, participants spatially attended to either the left or the right scene. At the beginning of each trial, a central cue instructed participants to detect either people or cars in the to-be-attended scene. The extent to which consistent object category information was present in scene-evoked activation patterns was estimated by testing how similar they were to the activation patterns evoked by isolated object category exemplars that were presented in separate runs. Consistent with previous findings, the task-relevant category was represented more strongly in OSC than the currently irrelevant category. This was true both for spatially attended and spatially unattended scenes, suggesting that category biases are implemented independent of spatial information. Responses in the posterior IPS regions contained similar category-specific information, however in a spatially-specific manner. These results suggest that in addition to generating space-based control signals, posterior IPS regions may play a role in the control of category-specific biases that are implemented in OSC in a spatially unspecific manner.

43.563 **Disambiguating the Effect of clutter on Boundary Extension**

Carmela Gottesman[1](cvgottesman@sc.edu); [1]University of South Carolina Salkehatchie

Perceptual processes involved in processing the spatial layout of scenes often result in memory distortions called Boundary Extension (BE); viewers tend to remember more of the scenes than they actually saw, as if they had seen more wide-angle views than they actually did. The influence of different scene characteristics on BE is still to a large degree unknown. Prior research looking at the effect of clutter on BE has led to contradictory findings. Natural scenes obtained from the database developed by Oliva and Torralba (2001) induced more BE for cluttered than uncluttered scenes (Gottesman, 2010). However, the pictures in these categories varied on other dimensions as well as clutter. Gottesman (2011) used computer modeled scenes with cluttered and uncluttered versions of each scene to control for any variables other than the number of objects presented in a given space. This study produced the opposite result: uncluttered images induced more BE. The current study sought to determine which result is the real effect of clutter and whether the discrepancy was caused by the variability of the scenes in the first study or the artificiality of the stimuli in the second study. Clusters of objects in real world environments were photographed (e.g., books and papers in a bookcase). In the cluttered version many more objects than in the uncluttered version were crowded into the same space. Participants viewed eight cluttered and eight uncluttered scenes in random order; picture version for each scene was counterbalanced across participants. As in the previous study using the uncontrolled natural scenes, the cluttered versions induced more BE than the uncluttered versions of the same scenes. These results reaffirm the probability that the more information present in a scene the more viewers need to expand their representation of the spatial context.

43.564 **Fuzzy memories and boundary extension: Individual scenes or episodic experiences**

Benjamin A. McDunn[1](bmcdunn@uga.edu), James M. Brown[1], Ralph G. Hale[1]; [1]University of Georgia

Visual memory for close-up views of scenes consistently exhibits a distortion known as boundary extension (BE), characterized by the report of seeing a wider-angle view than what was actually shown (Intraub & Richardson, 1989). Last year, we presented a series of experiments showing the first reported case (in a normal population) of memory for intact scenes not showing BE (McDunn et al., VSS 2013). Instead, a memory normalization effect was found in which participants seemed to be comparing test images to an averaged view of the studied stimulus set. This unusual finding was verified by several replications. The current study explores potential causes of this result using the standard paradigm used in the BE literature, a free-viewing study phase followed by a recognition test. Four conditions were created by independently manipulating two attributes of the scenes: whether the scenes appear in black and white versus full color, and whether the scenes depict the same location versus independent locations. The results indicate that strict memory normalization only occurs when both variables increase perceptual similarity between images in the set (black/white and same location). A clear effect of BE can be detected when color or different locations are applied to the images, with a slightly greater effect being found with the location variable. These results are explained in terms of the Fuzzy Trace Theory of memory (Reyna and Brainerd, 1995). Increasing the perceptual similarity within the image set likely creates a more gist-like memory trace that include all scenes viewed during the study phase of the experiment. An averaged episodic memory of the viewing experience increases the likelihood of gist recall during the recognition test, leading to normalization. When the images appear more perceptually dissimilar there is a greater likelihood of verbatim recall based on specific visual features, leading to the BE.

43.565 **Memory of a Scene Following Viewpoint Change Caused by Viewer Locomotion**

Hong-Jin Sun[1](sunhong@mcmaster.ca), Michael Comishen[1], Daniel Zhou[1], Katrina Radassao[1], Melanie Iarocci[1], Christopher Teeter[1]; [1]Department of Psychology, Neuroscince and Bahaviour, McMaster University, Canada

Viewpoint changes caused by an observer's locomotion lead to better scene recognition performance than that following equivalent movement of the scene. In studies testing change detection of a tabletop scene, the benefit of observer locomotion has been attributed to spatial updating through body-based information (Simons & Wang, 1998), or knowledge of a change of the reference direction gained through locomotion (Mou et al, 2009). In the current study, six experiments were performed using a similar paradigm but measuring both accuracy and reaction time of the response. Experiment 1-4 examined the effect of an external visual indicator introduced during the testing phase signalling the learning direction (as in Mou et al, 2009). Experiments 1 and 2 compared performance in the locomotion condition with table rotation condition, Experiments 3 and 4 compared performance in a short walking condition with conditions where body-based information was not reliable (disorientation or walking a long, curved path). Experiments 5 and 6 examined the effect of intrinsic reference direction information by aligning the orientation of the dominant axis of all the objects in the scene. Experiments 1-4 show that even with the visual indicator, performance in conditions that lacked normal locomotion was still significantly worse than that in the observer locomotion condition and that the visual indicator did not improve performance at all. However, in Experiments 5 and 6, performance for a scene composed of objects with consistent orientations was: (1) better than that for a scene composed to objects with random orientation and (2) comparable to that in observer locomotion condition. Overall we show that the body-based information in observer locomotion provides the most prominent information, while knowledge of a reference direction is useful but might only be effective in limited scenarios, such as scenes with an obvious and dominant orientation.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada (NSERC)

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Scene perception: Summary statistics

Monday, May 19, 8:30 am - 12:30 pm
Poster Session, Pavilion

43.566 Summary statistics of size: Fixed processing capacity for multiple ensembles but unlimited processing capacity for single ensembles

Mouna Attarha[1](mouna.attarha@gmail.com), Cathleen M. Moore[1], Shaun P. Vecera[1]; [1]University of Iowa

We assessed the processing capacity of establishing statistical summary representations of mean size in visual displays using the simultaneous-sequential method. Experiment 1 tested the capacity of summary representations across multiple ensembles. Four sets of stimuli, each composed of multiple circles with various diameters, were presented around fixation. The mean size of one of the four sets was either smaller or larger than that of the other sets. Observers searched for the odd set and reported whether its mean was smaller or larger. In the simultaneous condition, all four sets were presented concurrently; in the sequential condition, the sets appeared two at a time. Simultaneous performance was reliably worse than sequential performance, indicating that processing was limited capacity in this task. The limit was even as extreme as a fixed-rate bottleneck process. Experiment 2 tested the processing capacity of summary representations within a single ensemble. The same four sets, containing four items each, were arranged along an equally spaced grid to create the perception of a single set of sixteen items. Observers reported whether the average of the set was smaller or larger than the size of a probe circle that appeared afterward. Performance was equal across the simultaneous and sequential conditions, indicating unlimited-capacity processing. Contrary to existing claims, summary representations appear to be extracted independently only for items within single ensembles, and not across multiple ensembles. These results contribute to a developing understanding of capacity limitations in perceptual processing. When drawing similarities between the processes at each extreme, sensory and segmentation processes appear to have unlimited capacity while object and semantic processes have fixed capacity. The present study suggests that the formation of summary statistic representations for multiple ensembles across the visual field is more like object and semantic processing than it is like sensory or organizational processing.

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43.567 The effect of gain adaptation on the sensitivity of human perceptual judgements.

Santiago Herce Castañón[1](santiago.hercecastanon@psy.ox.ac.uk), Samuel Cheadle[1], Konstantinos Tsetsos[1], Christopher Summerfield[1]; [1]Department of Experimental Psychology, University of Oxford

Visual categorisation judgments often involve integrating multiple samples of information that occur in series. Some behavioural and neural studies suggest that evidence that is expected wield greater influence over decisions than evidence that is unexpected, whereas other studies have observed the converse.Here, we set out to test whether expected or unexpected samples are processed with higher gain using a hybrid detection/integration task.10 healthy human participants viewed a stream of between 1 and 8 Gabor patches in rapid succession, with a view to later estimating the average tilt of the distribution from which they were drawn. Distribution means fell close to +45 degrees or -45 degrees from vertical.To-be-categorised streams were succeeded by a stimulus that either contained (signal present trials) or did not contain (signal absent trials) a target Gabor patch embedded in noise, and prior to estimation participants judged whether the signal was present or absent; detection performance was titrated to approximately d'=1 on average.Target Gabors were either tilted consistently or inconsistently with the to-be-estimated category mean.Surprisingly, we found that Gabors inconsistent with category information were detected with heightened sensitivity.These findings are inconsistent with Bayesian models of perceptual inference, and suggest a heightened sensitivity to erroneous or unexpected information.

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43.568 Visual size averaging is parallel but depends on the range

Natalia Tiurina[1](natalyatyurina@gmail.com), Igor Utochkin[1]; [1]National Research University - Higher School of Economics (HSE)

Although the idea of visual averaging of multiple objects is widely recognized, there is still no consensus among researchers about its mechanism. Some authors suggest that size averaging is carried out in parallel over all items (Ariely, 2001; Chong & Treisman, 2003; Chong et al., 2008), while other consider it to be based on limited-capacity sampling (Myszek & Simons, 2008). Advocating the latter viewpoint Marchant, Simons, and De Fockert (2013) have recently reported a size averaging study where they manipulated set size and set heterogeneity independently. Their observers were good at averaging when a set included only two sizes distributed among all items (regular sets), but got poorer when the number of sizes increased with the set size (irregular sets). However, in their irregular condition the range of size variation was increasing systematically with the set size, while in the regular condition they used always the same two sizes that were very close to the mean. We suggest, therefore, that Marchant et al. could falsely recognize the effect of size variation as the failure of parallel averaging. We tested this in two experiments. In Experiment 1, we repeated Marchant et al.'s study and replicated their effects. In Experiment 2, we used the same range of variation for all conditions and changed the distribution within that range. Here, regular sets consisted of only smallest and largest items (instead of mean-similar ones in Experiment 1), and in irregular sets the intermediate sizes were added between these extremes. We found in the result that averaging accuracy remained almost the same for all regularity conditions and all set sizes, with even slight advantage of the regular condition. This indicates that size averaging still appears to be parallel but the accuracy of such averaging depends on the total range of variation of the target feature.

Acknowledgement: HSE Basic Research Center

43.569 The perception of variety in color segmented sets

Anton Gura[1,2](gura_anton@mail.ru), Igor Utochkin[1,2]; [1]Psychology Dept.,The National Research University Higher School of Economics, [2]Cognitive Research Laboratory, The National Research University Higher School of Economics

Observers can extract summary variety statistics from large sets of objects (Utochkin & Gura, VSS, 2014, this issue). Here we tried to find out how the visual system analyses visual variety statistics of segmented groups of objects. In Experiment 1 we tested whether variety statistics can be extracted from spatially overlapping sets segmented by color, as they are extracted from spatially separated sets (see Utochkin & Gura, this issue, Experiment 1). Observers were presented with sets of red and blue differently sized circles and had to determine which of sets had been more various in terms of size. The sets could be identical, or different by bandwidth, heterogeneity, or both. The results showed that variety discrimination was as efficient as in spatially separated sets indicating that the visual system is able to represent variety independently for different features. In Experiment 2, we tested whether segmentation of a set into heterogeneous subsets affects overall variety representation of that set. Observers were presented with sets of differently sized circles to the right and left from fixation. One of those sets was always colored homogeneously (in either red, green, or blue) and the other was always heterogeneous (including all three colors). Observers had to respond which of two sets was more various in terms of size, regardless of color variation. As in Experiment 1, size bandwidth and heterogeneity were manipulated. The results showed no effect of color heterogeneity on variety discrimination as compared to completely homogeneous sets (see Utochkin & Gura, this issue, Experiment 1). This indicates that variety information can be encoded along a sensory dimension (such as size) independently from variation of other features. This finding is in line with a standard two-stage model of vision considering ensemble summary statistics to be an output of early feature processing (Treisman, 2006).

Acknowledgement: The Program of Basic Research, Higher School of Economis

43.570 Seeing variety: The determinants of visual representation of variance statistics

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Visual summary statistics (such as the average along a sensory dimension) are efficient to construct a compact description of multiple objects when access to their individual features is limited. A number of recent studies have reported that variance is an important statistical feature affecting averaging (Corbett et al., 2012; Fouriezos et al., 2008; Im & Halberda, 2013). In our study, we directly addressed the ability to extract summary variance statistics from visual sets. In all experiments, observers were briefly presented with sets of differently sized circles to the right and left from fixation and had to respond which one was more various. In Experiment 1 two factors – bandwidth and heterogeneity (the number of unique sizes per set) – were manipulated. We found in the result that bandwidth appears a predominant factor of variety discrimination. In Experiment 2, the smoothness of size distribution was manipulated within the constant bandwidth via additional intermediate sizes between smallest and largest items. We found that the sharpest two-peaks distributions consisting only of extremes are estimated as being more various than smoother ones. In Experiments 3-5, we used the same factors as in Experiment 1 and tested whether variety

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discrimination depends on additional factors such as mean size of circles, their spatial density, or numerosity. In Experiment 6, we precued either of sides from fixation drawing attention to one of the sets. Although mean size, density, numerosity, and attention manipulation elicited biases in judging variety of identical distributions, they did not affect overall discriminability of different distributions replicating the results of Experiment 1. So, the only found principal determinants of variety perception were those actually related to stimulus physical variance. The results of Experiments 3-5 also show that statistical representations of variety are rather abstract and and Experiment 6 shows that they are extracted in parallel.

Acknowledgement: The Programme for Basic Research, the Higher School of Economics

43.571 **Rapidly estimating numerosity independent of size-related distance or occlusion** Guillaume Riesen[1](guillaume.riesen@gmail.com), Harald Ruda[1], Ennio Mingolla[1]; [1]Computational Vision Laboratory, Northeastern University

Finding objects in natural environments presents a challenge for even simple objects with known properties. Because of occlusion and distance, the number and extent (visual angle) of visible surfaces do not directly convey the number of objects seen. Are those three reddish surfaces one nearby partially occluded apple or three distant apples? Resolving such ambiguities seems effortless for human observers. To benchmark human performance, we asked subjects to indicate which of two briefly pictured trees had more apples. Trees were generated in a virtual environment, and pairs were constructed with variations in occlusion, distance, or number of visible apples. Preliminary results show good performance (>95% correct) on the task, despite some less fruit-laden trees having double the visible apple area of their partners. Subjects did not simply respond to the extent of visible apple surfaces; their judgments were robust to variations in occlusion or visual angle. We believe this is the result of a multi-stage process similar to Xu and Chun's (TiCS, 2009) "individuation and identification" stages, where proto-objects with low-level features are first spatially localized then further refined into identifiable objects. We created a simple algorithm to investigate this hypothesis. First, it segments pixels with "tree-like" color (RGB values) by blurring and thresholding. It then tags apple-colored pixels within these tree-like regions. These pixels are convolved with a circular template whose radius depends on the area of the tree-like region. Local maximums give locations of apples that might explain the observed pixels, given the estimated tree size. This system can distinguish between a cluster of patches representing a single heavily-occluded apple nearby, versus multiple apples at a distance. It performs comparably to humans on our task, suggesting that subjects group proto-objects derived from visible patches into individual apples as a basis for numerosity judgments.

Acknowledgement: CELEST, an NSF Science of Learning Center (NSF SBE-0354378)

43.572 **Neural Representation of Ensemble Orientation in Human Visual Cortex** Ruosi Wang[1](ruosiwang@fas.harvard.edu), Yaoda Xu[1]; [1]Harvard University

Human observers are experts at extracting summary statistics from a variety of visual features such as orientation and size. Although extensive behavioral studies have documented the existence of such ensemble representations, few studies have addressed the underlying neural mechanism. In this study, using fMRI and multi voxel pattern analysis, we investigated how ensemble orientation is coded in human visual cortex by examining fMRI response patterns in retinotopically defined areas as well as high-level object processing regions. We generated ensemble displays containing Gabor patches with two different orientations (heterogeneous ensembles) as well as ensemble displays containing Gabor patches with a single orientation (homogenous ensembles). Using support vector machine, a linear classifier, we will examine whether heterogeneous and homogenous ensembles sharing the same mean orientation would be represented similarly along the visual processing pathways.

Acknowledgement: This research was supported by NIH grant 1R01EY022355 to Y.X.

43.573 **Plinko: A spatial probability task to measure learning and updating.** Alex Filipowicz[1](alsfilip@uwaterloo.ca), Derick Valadao[1], Britt Anderson[1,2], James Danckert[1]; [1]Department of Psychology, University of Waterloo, [2]Centre for Theoretical Neuroscience

Research has demonstrated that humans efficiently learn the statistics of their visual environment (e.g., Fiser & Aslin, 2001). Typical studies present participants with series' of events and ask them to predict which event will occur on specific trials. Responses are then aggregated over bins of trials to represent a probability distribution of participant predictions. Although informative, these tasks provide limited information about how participant expectations evolve over the course of a task. We present a novel spatial probability task that attempts to overcome this limitation. Based on the game 'Plinko' (the modern incarnation of Galton's Bean Machine), participants view balls that drop through pegs and land in slots. On every trial, participants are asked to estimate how likely a ball will fall in each slot. Participants adjust a cup or bars under the slots to represent their likelihood estimations. We exposed participants to four distinct distributions of ball drops and measured how accurately they could represent each distribution (Experiment 1) and shift from one distribution to the next (Experiment 2). Rather than representing participant expectations by building probability distributions over multiple trials, our measures provide a probability distribution on each trial of the task. Participants managed to use the cup to accurately track the mean and variance of each distribution by adjusting the cup's center position and width throughout the task. Participants were also efficient at using the bars, matching the computer's distributions with an average accuracy of 80%. Participants also managed to effectively shift from one distribution to the next using either the cup or bars, and this without being made explicitly aware that any changes would occur. These results suggest that our task provides an effective measure of spatial probability learning while also providing a rich representation of changes in participant predictions over the course of the task.

Acknowledgement: Canadian Institutes of Health Research, Natural Sciences and Engineering Research Council of Canada

43.574 **Summary statistics influence how individuals are perceived in noise.** Kyle Killebrew[1](k.killebrew@hotmail.com), Christopher Blair[1], Gideon Caplovitz[1]; [1]Psychology, University of Nevada Reno

It has been consistently demonstrated that human observers are able to extract statistical averages from groups of objects in a variety of different feature domains, including but not limited to orientation, color, size, and facial expression. However, little known about how this summary information is used and what function it may serve. Here, we tested the hypothesis that one function may be to fill-in information under conditions of visual uncertainty.That is to say, in suboptimal viewing conditions in which object individuation may be difficult, the visual system uses summary information to represent individual items. The current study was designed to explicitly test a prediction made by this hypothesis. The hypothesis makes a basic prediction that the perceived variability of a group should be underestimated, particularly in the presence of noise.That is because the percept of each individual item will be biased towards the extracted average. In two experiments, we used adaptive staircase procedures in which participants judged which of two groups of varying sized circles (two interval forced choice) had the greater mean (Experiment 1) or was more variable (Experiment 2). The results of Experiment 1 indicate that the presence of noise did not significantly impair participants' ability to extract the mean size of the array (Weber fraction). This suggests that in the presence of noise, this information is not lost. Consistent with the hypothesis, the results of Experiment 2 indicate that the perceived variability in size was significantly underestimated in the presence of noise. The results of this study suggest that the rapid and potentially pre-attentive extraction of summary information may be used in a top-down fashion to influence how the individuals of a group appear.

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43.575 **Foveal input is not required for ensemble coding of emotional faces** Katherine Wood[1](katherinemwood@berkeley.edu), Benjamin Wolfe[1], Anna Kosovicheva[1], Allison Yamanashi Leib[1], David Whitney[1]; [1]University of California Berkeley

Observers can reliably perceive the average of an ensemble of stimuli (Watamaniuk et.al, 1992; Dakin et.al, 1997; Chong and Treisman, 2001), including high-level stimuli such as faces (Haberman and Whitney, 2007). However, it has been suggested that ensemble coding is simply averaging of foveal information over successive saccades. To test this, we performed a study in which subjects viewed sets of 24 faces with and without foveal information available. Face stimuli were selected from a set of 147 morphs, with expressions ranging from happy to sad to angry. After 1500 ms of free viewing, subjects were asked to report the mean expression of the ensemble. In one condition, subjects had their view of the array of faces unobstructed; in a critical second condition, a gaze-contingent circular occluder (2.6° in diameter) completely blocked foveal information. Subjects performed equally well across the occluded and non-occluded conditions, with no significant difference in response error. Additionally, when foveal information was occluded, subjects spent significantly more time fixating between faces in the ensemble (rather than directly on a face) compared

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to the unobstructed condition. In a follow-up experiment, we varied the proportion of faces that were visible in the set; we found that subjects' performance improved as more faces were presented, regardless of the foveal stimulation, indicating that they were integrating information from multiple faces in the display under both non-occluded and occluded conditions. Thus, while subjects adopted different fixation patterns between conditions, opting to fixate off of a face more in the occluded condition, performance on the task was unaffected by the loss of foveal information. This indicates that ensemble perception of faces is not determined solely by foveal input, but can operate entirely on information in the peripheral visual field.

43.576 **Neural computation of scene gist with and without attention** Iris Groen[1](i.i.a.groen@uva.nl), Sennay Ghebreab[2], Victor Lamme[1], Steven Scholte[1]; [1]Cognitive Neuroscience Group, Department of Psychology, University of Amsterdam, [2]Intelligent Systems Lab, Institute of Informatics, University of Amsterdam

Visual attention is traditionally thought to play a crucial role in binding of image features into complex visual representations. Recent findings from natural scene research challenge this idea, by showing that complex scenes can still be categorized under conditions of diminished attention. One possibility is that this preserved capacity is mediated by a 'gist' representation: a global scene impression that is formed even when the scene is outside the focus of attention. Here, we investigated to what extent the brain still processes global information when attention is diverted away from the scene. We presented several hundreds of natural scenes while subjects performed, in different blocks, a man-made vs. natural categorization task (full attention on the scene), a central letter task (focal attention diverted) and a peripheral outline task (distributed attention diverted). Simultaneously, EEG was recorded to compare ERP amplitudes for the same scenes presented under these different attention manipulations. At early occipital electrodes, evoked responses for man-made versus natural scenes differed reliably from 100 ms onwards, regardless of attentional set. At parietal-occipital electrodes, however, reliable differences appeared around 200 ms, but were only observed under full attention, not when focal or distributed attention was directed elsewhere. Using computational modeling, we show that the ERP differences are likely driven by differences between man-made and natural scenes in a biologically plausible image statistic called spatial coherence (SC) that reflects integrated local contrast across the entire scene (Groen et al., 2013, J Neurosci). Regression analysis of single-trial ERP amplitude on image statistics revealed a selective contribution of SC to evoked activity when a significant difference between man-made and natural scenes was present. Overall, these results suggest that the brain does extract global information under diminished attention, but that this information is only statistically integrated and broadcasted across the visual system under full attention.

43.577 **The effects of spatial organization on numerosity judgments in real-world scenes** Stacey Rashford[1](stacey.rashford@gmail.com), Elan Barenholtz[1]; [1]Department of Psychology, College of Science, Florida Atlantic University

How does the spatial organization of objects affect their perceived numerosity? Previous studies have demonstrated that when simple, homogenous stimuli (dots), are presented in a regular configuration, they are judged to be more numerous than when presented in a random configuration (Ginsburg, 1978). However, such homogeneous stimuli are highly conducive to perceptual organization principles, such as grouping, that may not apply to real-word objects. In the current study, we examined the role of spatial organization of real-world scenes made up of everyday objects. Stimuli consisted of photographs of 40 different collections of between 11 and 32 office items (e.g. stapler, computer mouse, etc.) arranged on a desk. Each collection was used to generate two stimuli, one with the objects arranged in an organized manner and one in a disorganized manner (80 trials total). Both the organized and disorganized versions of each collection contained the same objects, centered on the same spatial locations; however in the organized condition the individual orientations of the items were parallel with each other and the contours of the desk while in the disorganized condition they were in random orientations. Each scene was presented for 500 msec. after which the participant guessed the number of items in the scene. While overall accuracy (i.e. measured as difference from actual numerosity) was similar across conditions, we found that that disorganized collections were judged as having more objects than organized collections. Thus, spatial organization produces an opposite effect in patterns of simple homogenous stimuli—where it leads to a perception of lower numerosity—and real-world scenes—where it leads to a perception of higher numerosity. This difference may depend on the subjective sense that disorganized configurations of real-world objects are 'cluttered', relative to typical/preferred organizations, leading to higher perceived numeorsity.

43.578 **Improving computational models of early visual cortex using single image ERP data** H.Steven Scholte[1](h.s.scholte@uva.nl), Sennay Ghebreab[1]; [1]University of Amsterdam, Amsterdam Brain and Cognition center

In the past we have generated models of the early visual system (Scholte et al., 2009, Ghebreab et al, 2011,) that are capable of generating summary statistics of images related to contrast energy and spatial coherency. These parameters group visual images into a structures space that goes from, on one dimension, have a high likelihood of having features like man-made figure-ground objects to having a high likelihood of having features like natural and fragmented. The other dimension organises the images in terms of energy. These summary statistics can explain between single-image ERP's well, particularly around 120 ms, but also extending later in time. Relevantly, the summary statistics derived from the model explained more variance in the ERP than Fourier, or third and fourth order statistics (Groem et al., 2012, 2013). Here we extend this approach by formally using two separate datasets of ERP responses towards natural images. One for fine-tuning parameters via cross-validation and one for final validation. Using this we now not only model on/off cells but also simple cell responses. Adding the parameters obtained from simple cell responses improves the explained variance of our model thought-out the range of modeled information, but in particularly, and as expected after the peak explained variance of the on/off cells, 140 ms. We will also present data in which we use these parameters to see to what degree we can 'explain' away differences between ERP responses from, for instance animal vs non-animal, images.

43.579 **Ensemble Perception of Multiple Crowd Characteristics** Allison Yamanashi Leib[1](ayleib@gmail.com), Yang Bai[1], Anna Kosovicheva[1], Kelly Chang[1], Amrita Puri[2], Lynn Robertson [1], David Whitney[1]; [1]Psychology, University of California Berkeley , [2]Psychology and Counseling, University of Central Arkansas

Previous research demonstrates that individuals can extract single summary statistics from crowds—even when faces are viewed rapidly at speeds of 20 Hz. (Haberman & Whitney, 2009). However, it remains unclear whether individuals can extract multiple high-level ensemble percepts in a similarly efficient manner. To address this question, we created a set of face stimuli morphed along two dimensions; emotion (from happy, to sad, to angry) and identity (from Caucasian, to Asian, to African American). The stimulus set was psychophysically controlled to be equally discriminable along both dimensions. Participants viewed a sequentially displayed crowd of 18 faces, with each face presented for 50 ms. After the display disappeared, participants were cued to choose either the average emotion or the average identity of the crowd using a method of adjustment task. Participants extracted both the average emotion and average identity of the crowd without a pre-cue, indicating that participants were able to successfully ensemble code both dimensions. Additionally, participants were able to estimate the average emotion/identity more accurately when presented with the crowd compared to a single-face subset. This suggests that participants were integrating information from multiple faces and not randomly picking one emotion or identity from the crowd. Results from other experimental controls, such as crowds comprised of scrambled faces, indicate that participants are not merely relying on low-level features to extract multiple dimensions, but rather are engaging in higher-level processing strategies. Taken together, these results indicate that individuals may utilize multiple ensemble percepts to efficiently analyze complex scenes.

Tuesday Morning Talks

Perceptual organization: Surfaces, segmentation, shapes and objects

Tuesday, May 20, 8:15 - 9:45 am
Talk Session, Talk Room 1
Moderator: Edward Adelson

51.11, *8:15 am* **Reconstructing the 'third dimension' from 2D shapes: Evidence from the perception of balance** Chaz Firestone[1](chaz.firestone@yale.edu), Frank Keil[1]; [1]Department of Psychology, Yale University

Suppose you are shown an outline of a simple 2D shape, and are then asked to estimate where it would balance on your finger. What sort of 3D interpretation does your visual system assign to the shape? In a series of experiments, we discovered that center-of-gravity (COG) estimates for asymmetric 2D shapes are systematically biased, such that long and narrow shape-parts are underweighted, and stouter and rounder shape-parts are overweighted. Why should this be? We theorized that this bias emerges because the visual system assumes that narrower shape-parts in 2D are literally *thinner* in 3D — even when no such depth or thickness information is actually present in the image. This hypothesis was tested in two quite distinct ways. First, the COG-estimation bias was found to depend on the presence of visible contours; compared to their COG estimates for shapes, subjects more accurately estimated the centroids of dot-fields whose convex hulls formed the shapes from the earlier COG-estimation task — even though centroids of dots are formally equivalent to COGs of shapes. Next, we used a 3D printer and laser-cutter to physically build uniformly thick objects from the shapes used in the COG-estimation task, and found that viewing (without handling) these real-life objects during COG estimation moved subjects' estimates closer to the shapes' true COGs. We suggest that the visual system assigns rich, irregular, volumetric interpretations even to simple 2D shapes, and that the nature of such representations can be revealed in surprisingly precise and specific ways by investigating perceptions of balance and stability.

51.12, *8:30 am* **Visual cue diagnosticity for boundary detection in natural scenes: A computational study** David Alex Mély[1](david_mely@brown.edu), Junkyung Kim[1], Mason McGill[2], Yuliang Guo[3], Thomas Serre[1]; [1]Department of Cognitive, Linguistic and Psychological Sciences, Brown University, [2]Computation and Neural Systems, California Institute of Technology, [3]Division of Engineering, Brown University

Previous work has shown that multiple cues may signal object boundaries (Rivest & Cavanagh, 1996) but little is known about the diagnosticity of these cues for natural scenes, either individually or in combination. For this study, we constructed a database of color binocular video sequences with a consumer-grade stereo camera. The dataset includes a variety of places (from streets to parks), settings (from summer to winter) and objects, to minimize bias. Image annotations were collected from participants who were instructed to draw clearly visible object boundaries. We started from a standard model of the primary visual cortex (a battery of center-surround and oriented receptive fields at multiple spatial frequencies with parameters constrained by neurophysiology), and extended it to include biologically realistic mechanisms for color, binocular disparity and motion processing. In this work, we explore the statistical correlations between these cues, evaluate their diagnosticity and learn their optimal combination using the framework by Martin et al (2004). We found color and contrast to be most diagnostic for the presence of boundaries in natural scenes. Stereo and motion were the least diagnostic cues. Surprisingly, we found visual cues to be relatively uncorrelated both at boundary and non-boundary locations. Divisive normalization (Heeger & Carandini, 1992) over a carefully selected pool of units was critical to achieve good accuracy. For all cues, a higher-order texture-based visual representation as proposed by Martin et al (2004) was found to be more diagnostic than a representation based on the direct output of orientation-tuned units. Overall we found that combining multiple cues improved contour detection beyond any of the cues presented in isolation suggesting that our visual system may benefit from the combination of multiple visual cues for boundary detection.

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51.13, *8:45 am* **Dynamic Illusory Size-Contrast: A relative-size illusion modulated by stimulus motion and eye movements** Ryan Mruczek[1](rmruczek@unr.edu), Chris Blair[1], Gideon Caplovitz[1]; [1]Department of Psychology, University of Nevada, Reno

The perceived size of an object is constructed by integrating multiple sources of information, including but not limited to retinal image size, physical and perceived distance, and the relative size of different objects in a scene. Here, we introduce a novel size-contrast illusion that highlights the role of dynamic visual information in modulating the contribution of different sources of information in determining the perceived size of an object. In the Dynamic Illusory Size-Contrast (DISC) effect, the viewer perceives the size of a target bar to be shrinking when (1) it is surrounded by an expanding box and (2) there are additional dynamic cues such as eye movements, changes in retinal eccentricity of the bar, or changes in the spatial position of the bar. Using a nulling technique, we systematically explored how these dynamic factors contribute to the DISC effect. Importantly, the expanding box was necessary but not sufficient to induce an illusory percept, distinguishing the DISC effect from other size-contrast illusions. We propose that the dynamic nature of the stimulus leads to greater uncertainty regarding the retinal size of the target object. As a result, other sources of information, such as relative size, contribute more to its perceived size, thereby increasing the magnitude of the illusory percept. Given the compelling nature of the DISC effect and the inherently dynamic nature of our environment, these factors are likely to play an important role in everyday size judgments. In addition, the DISC effect is not limited to a highly specific set of stimulus parameters; we highlight the generality of the illusion using stimulus configurations of classic size-contrast illusions (e.g., the Ebbinghaus and Delboeuf illusions).

Acknowledgement: NIH: NIGMS and NEI

51.14, *9:00 am* **Enigmatic cases of modal amodal completion: What do modal and amodal percepts represent?** Vebjørn Ekroll[1](vebjorn.ekroll@ppw.kuleuven.be), Tom R. Scherzer[2]; [1]Laboratory of Experimental Psychology, University of Leuven (KU Leuven), [2]Institute of Psychology, University of Kiel

In the "occlusion illusion" an object hidden behind a static occluder is perceived as though it were less occluded than it actually is (Palmer, Brooks & Lai, 2007, Perception, 36(5), 650–669). We confirm and extend this finding using a stimulus with a moving occluder. In agreement with Palmer et al.'s findings and their partial-modal-completion hypothesis, we found that the illusion is indeed related to the sensory evidence for occlusion. Our experiments also confirm Palmer et al.'s speculation that the occlusion illusion involves an intriguing, seemingly paradoxical percept. In our experiments, subjects viewed an opaque disk with an open sector rotating in front of a background and indicated a) the perceived angular extent of the occluding disk sector and b) the perceived angular extent of the part of the background experienced as directly visible. While the perceived angular extent of the occluding disk sector corresponded to the physical extent of the stimulus, the perceived angular extent of the background region experienced as directly visible through the open sector in the occluder was clearly overestimated. Thus, the sectors of the circle experienced as directly visible and occluded sum to more than 360 degrees, which – much like Escher's well-known paintings – makes the total percept an "impossible figure". We argue that the key to resolving this paradox is to question the seemingly self-evident tacit assumption that occluded portions of a visual scene are represented by amodal percepts, while unoccluded portions of a scene are represented by modal percepts. Instead, we propose that visual percepts are experienced as modal whenever they are based on sufficiently conclusive sensory evidence. Conversely, they are experienced as amodal when this is not the case. Functionally, this perceptual representation of the conclusiveness of the sensory evidence underlying perceptual inferences might be more useful than estimates about optical visibility.

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51.15, *9:15 am* **Bending the truth: Generative models of shape for inferring transformations** Patrick Spröte[1](patrick.sproete@googlemail.com), Roland Fleming[1]; [1]University of Giessen (Germany)

We can usually tell whether a tin can on the ground has been crushed or kicked, or if a cookie on a plate has been bitten. In general, humans readily make judgments about the generative processes and transformations that have been applied to objects. Conversely, our ability to recognize objects is often robust across such shape transformations: we can still identify the can even though it has been dented. This ability to determine and discount the causal history of objects suggests the visual system may separate the observed shape of an object into original (untransformed) elements plus the transformations that were applied to it. However, almost no empirical work has investigated to what extent we can extract information about shape transformations and which structural and configural information is used to determine causal history. We conducted two experiments in which we sought to shed light on these questions, using 'bending' as an example transformation. In Experiment 1, we investigated whether subjects could detect and asymmetrically match the degree of transformation (here bending) applied to parametrically generated random 3D shapes. Subjects adjusted the degree of bend applied to a standard object until it appeared as bent as the test object, which had a different 3D orientation. In Experiment 2, observers had to identify the individual objects from Experiment 1 across different transformations. Subjects saw bent versions of each shape and had to identify the corresponding object from a set of 'untransformed' 3D shapes. From our two studies, we conclude that subjects extract information about certain transformations applied to shapes, while ignoring other differences. Our results therefore provide first evidence for scission of a shape's representation into its causes – a base shape and a transformation applied to it.

Acknowledgement: FKZ: 01GQ1111 - "Towards a Neural Theory of 3D Shape Perception"

51.16, *9:30 am* **Puffball Part Segmentation: Psychophysical and Statistical Evaluation** Nathaniel Twarog[1](nathanieltwarog@gmail.com), Edward Adelson[1]; [1]Massachusetts Institute of Technology

The segmentation of silhouettes into parts is a basic, long-standing problem in the comprehension, representation, and analysis of shape. Various approaches have been proposed which utilize two-dimensional shape properties; given that both the stimulus and output are two dimensional, use of two-dimensional analyses makes intuitive sense. The success of such approaches, however, has been limited. We propose a different approach, which models the selection of silhouette parts by first mapping the silhouette to a canonical three-dimensional shape, and then performing a simple and intuitive analysis of this new three-dimensional analogue. As previously described, Puffball inflation provides us with a robust, intuitive, scale invariant three-dimensional shape (Twarog et al. 2012), and a simplified application of the 3D Minima Rule (Hoffman and Richards, 1984), identifies part boundaries that can be projected onto the original silhouette. Using a dataset of human segmentations on 80 real-world silhouettes collected by DeWinter and Wagemans (2006), we present several psychophysical and statistical evaluations comparing the part-line predictions of Puffball to those of two approaches based on minima of negative contour curvature, the Necks and Limbs algorithm (Siddiqi and Kimia, 1995) and the Short Cut Rule (Singh et al., 1999). In each of these evaluations, Puffball part segmentation performs as well as or better than the minima-based approaches; most notably, Puffball identifies part-line endpoints more consistent with human judgments that the competing models. These results suggest that the two-dimensional patterns of part-line segmentations on which existing Minima Rule-based approaches are based, though valid as observations, do not necessarily comprise the computational chain through which such part-line judgments are made. As Puffball part segmentation exhibits many of these same patterns, we propose that these observed two-dimensional patterns are in fact the indirect effects of a three-dimensional computation.

Acknowledgement: NIH National Eye Institute

Visual working memory: Neural mechanisms

Tuesday, May 20, 8:15 - 9:45 am
Talk Session, Talk Room 2
Moderator: Timothy F. Brady

51.21, *8:15 am* **Induced alpha rhythms reveal the content and quality of visual working memory representations with high temporal precision** David E. Anderson[1,2](dendersn@gmail.com), John T. Serences[3,4], Edward K. Vogel[1,2], Edward Awh[1,2]; [1]Department of Psychology, University of Oregon, [2]Institute of Neuroscience, University of Oregon, [3]Department of Psychology, University of California, San Diego, [4]Neuroscience Graduate Program, University of California, San Diego

In line with the hypothesis that neuronal oscillations coordinate the cellular assemblies that represent items in working memory (WM), we show that activity in the alpha frequency band (8-12 Hz) can be used to decode the content and quality of representations stored in visual WM. We acquired EEG data during an orientation WM task, and used a forward encoding model of orientation selectivity to reconstruct orientation-specific response profiles or channel tuning functions (CTFs). Because of reliable covariations between the spatial distribution of alpha power and the stored orientation value, this approach enabled the moment-by-moment tracking of the stored orientation during both the encoding and delay epochs of the trial. We measured the pattern of evoked and induced oscillatory power, which correspond to stimulus-driven and endogenously generated responses, respectively. Critically, these EEG-based CTFs were robust predictors of both between- and within-subject differences in mnemonic precision when decoding the spatial distribution of induced – but not evoked – alpha power. Experiments 2 and 3 established that these EEG-based CTFs are contingent on the voluntary storage goals of the observer. When observers were given a post-sample cue to store or drop the memorandum, the resulting CTF was sustained in the "store" condition and rapidly eliminated following the "drop" cue. When observers were instructed to store one of two simultaneously presented stimuli, only the stored item was represented in a sustained fashion throughout the delay period. These findings suggest that the synchronization of neural activity in the alpha frequency band plays a central role in the active storage of information in visual WM, and demonstrate a powerful approach for tracking the precision of online memories with high temporal resolution.

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51.22, *8:30 am* **Neural correlates of visual working memory precision in frontal and parietal cortex** Qing Yu[1](qing.yu.gr@dartmouth.edu), Won Mok Shim[1]; [1]Department of Psychological and Brain Sciences, Dartmouth College

Previous research on visual working memory suggests that multiple brain regions, including frontal, parietal and early visual cortex, are involved in maintaining visual information in working memory during a delay period. However, the exact role of each of these areas in visual working memory and their subsequent behavioral relevance have long been under debate. Here, using fMRI and a forward encoding model (Brouwer & Heeger, 2009; 2011; Ester et al., 2013), we directly assess the behavioral relevance of the brain areas involved in visual working memory maintenance during a precision task (Wilken & Ma, 2004). On each trial, subjects were presented with two sequential gratings of different orientations and were cued to remember the orientation of one of the gratings. After a 10 s delay, subjects reported the orientation of the remembered grating by rotating a test grating to match the remembered orientation. The precision of a subject's working memory on a given trial was measured as the angular distance between the orientation of the reported and the to-be-remembered grating. Our results show that population-level orientation tuning functions peak at the remembered orientation, and are retained over memory delay in intraparietal sulcus (IPS) and frontal eye fields (FEF), as well as early retinotopic cortex (V1/V2/V3). Furthermore, as memory precision increases, the model fit of the orientation tuning functions improves and the offset of the tuning from the remembered orientation decreases, indicating that the quality of orientation tuning while sustaining visual information is strongly correlated with working memory precision at the single-subject level. Our findings suggest that feature-selective tuning functions are not only maintained in early visual cortex, but also in higher cortical areas, including IPS and FEF, during a visual working memory task; and additionally the precision of this population tuning is predictive of the precision of one's memory representation.

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51.23, *8:45 am* **Neural evidence for the flexible use of working memory and episodic memory in prospective remembering**
Jarrod Lewis-Peacock[1,2](jalewpea@utexas.edu), Jonathan Cohen[3,4], Kenneth Norman[3,4]; [1]Dept. of Psychology, Univ. of Texas, Austin, TX, [2]Inst. for Neurosci., Univ. of Texas, Austin, TX, [3]Dept. of Psychology, Princeton Univ., Princeton, NJ, [4]Princeton Neurosci. Inst., Princeton Univ., Princeton, NJ

How do we remember to execute a specific goal at the appropriate time (i.e., perform "prospective memory")? We can use an effortful strategy -- actively maintaining the goal in working memory -- or a reflexive strategy -- relying on external cues to trigger retrieval of the goal (McDaniel & Einstein, 2000; Reynolds, West, & Braver, 2009). The flexible choice of strategy involves a tradeoff between effort and performance, and depends on the availability of cognitive resources and the likelihood of goal retrieval. We designed a fMRI study to track, on a trial-to-trial basis, the use of working memory versus episodic memory to achieve a delayed goal. Each trial began with a target picture, followed by a variable-length sequence of 2-sec memory probes, each containing two pictures and a string of letters. Participants were required to make repeated lexical judgments about the letter strings until the picture target reappeared (between 2 and 42 sec after its introduction). We varied the difficulty of the lexical judgments and the degree of proactive interference associated with the target. We reasoned that when a trial involved lexical judgments that were more demanding, participants would be less likely to maintain the picture target in working memory, relying instead on retrieval from episodic memory. On other trials, high proactive interference would interfere with episodic memory retrieval, thereby biasing participants to use working memory to maintain the target. Multivariate pattern analysis of fMRI was used to identify target-related activity during each trial. Prospective memory success was associated with elevated estimates of target activation at the moment it reappeared (which could indicate either working memory or episodic memory use). Critically, target activations prior to its reappearance (indicative of working memory use) were more predictive of success on trials designed to bias the use of a working memory strategy.

Acknowledgement: The John Templeton Foundation

51.24, *9:00 am* **Reconstructing stimulus-specific working memory representations in human visual, parietal, and frontal cortex.**
Edward Ester[1](edward.ester01@gmail.com), John Serences[1,2]; [1]Department of Psychology, University of California, San Diego, [2]Neurosciences Graduate Program, University of California, San Diego

Visual working memory (WM) enables the temporary storage of information in an "online" state. Substantial evidence suggests that WM storage is mediated by a broad network of frontal, parietal, and sensory cortical regions, but the precise contribution(s) of these regions to storage are unclear. One emerging view – informed by invasive electrophysiological recordings in non-human primates and human neuroimaging work - is that stimulus-specific information is represented by sustained patterns of activation in visual cortex, while sustained delay-period-specific responses in frontoparietal regions reflect the operation of "top down" attentional factors that refresh these sensory representations and/or mitigate the influence of distracting information. However, here we show that sustained patterns of activation observed in parietal cortex during WM storage faithfully represent specific features of a remembered stimulus. On each trial, participants were shown two gratings (one per visual hemifield) and postcued to remember one of these stimuli over a 10 second delay. Participants then adjusted the orientation of a "probe" grating to match the remembered target. Using fMRI and a forward encoding model of orientation selectivity, we attempted to reconstruct orientation-selective response profiles in functionally defined regions of visual (V1-hV4v/V3a), and parietal cortex (IPS0-3), as well as an anatomically defined region of frontal cortex implicated in WM storage (sPCS). This analysis revealed robust, graded orientation-selective response in multiple visual (V1-hV4) and inferior parietal (IPS0-1) ROIs both contralateral and ipsilateral to the cued grating (but not the uncued grating). Conversely, orientation-selective responses could not be recovered in any of the superior parietal (IPS2-3) or frontal (sPCS) ROIs that we examined. These results suggest that both visual and inferioparietal cortex play an important role in representing specific stimulus attributes during WM storage.

Acknowledgement: NIH R01 MH092345 (J.T.S.) and T32 MH020002 (E.F.E.)

51.25, *9:15 am* **Working memory accumulates more information from real-world objects than from simple stimuli: Evidence from contralateral delay activity**
Timothy F. Brady[1](tbrady@wjh.harvard.edu), Viola S. Störmer[1], George A. Alvarez[1]; [1]Department of Psychology, Harvard University

Visual working memory (WM) is an active storage system into which visual information can be encoded to make it resistant to interference from new perceptual input. Information about simple stimuli – colors, orientations – is encoded into visual WM rapidly: in under 100ms, WM 'fills up', revealing a stark capacity limit of 3-4 items. However, for real-world objects, the same limits do not hold: with increasing encoding time, observers store more real-world objects and do so with more detail (Brady et al., 2009). We tested whether the benefit of extra time for real-world objects reflects active WM storage, or whether this benefit instead reflects the consolidation of information into long-term memory (LTM), as is traditionally assumed (e.g., Cowan, 2001; Lin & Luck, 2012). To address this directly, we measured the contralateral delay activity (CDA) – a marker of WM capacity, which reflects active storage of visual information in the parietal lobe (Vogel & Machizawa, 2004). We manipulated encoding time (200ms and 1s) for real-world objects and found that: (1) the CDA continues to build in strength during the entire 1s encoding interval, and (2) this results in a CDA that is significantly larger after 1s than after 200ms ($t(11)=2.8$, $p=0.01$). This shows that the ability to remember more information about real-world objects with increased encoding time does not merely reflect LTM consolidation, but reflects active storage in WM. These results demonstrate that WM shows different properties for simple stimuli and real-world stimuli, and suggest that more work is needed to understand the properties of the WM system as we use it in the real world.

Acknowledgement: T.F.B. was funded by a Harvard Mind/Brain/Behavior Post-doctoral Fellowship. V.S.S. was funded by a Marie Curie fellowship (EU Grant PIOF-GA-2012-329920).

51.26, *9:30 am* **Decoding reveals distractor modulation of visual short-term memory contents in occipital but not in parietal cortices**
Katherine Bettencourt[1](kcb@wjh.harvard.edu), Yaoda Xu[1]; [1]Harvard University, Department of Psychology

Recently, there has been considerable debate on where the contents of visual short-term memory (VSTM) are stored. Univariate fMRI analyses have suggested that regions in the parietal lobe, in particular superior intraparietal sulcus (IPS), play a central role in VSTM storage. In contrast, fMRI multivariate pattern analysis (MVPA), has implicated primarily sensory cortices, in particular early visual cortex, in the storage of visual information. These findings prompt two important questions: 1) what does the dissociation between these techniques tell us about how VSTM is stored in the brain, and 2) if early visual areas, whose main role is to process incoming visual stimuli, are involved in the storage of VSTM, what happens to that stored information when subsequent visual information must be processed? We examined these questions across three fMRI studies using MVPA. We found, supporting previous univariate findings, that the memory of a particular orientation could be successfully decoded in superior IPS, regardless of the presence of distracting visual information during the delay. In early visual cortex, however, decoding performance depended, not only on whether distractors were present, but also on participants' foreknowledge of their presence. When participants knew distractors would be present, decoding performance for the remembered grating fell to chance. Decoding accuracy rose as the probability of distraction decreased, suggesting a switch in participants' strategy based on their knowledge of whether distractors would be present. Behavioral performance was not affected by the presence of distractors. These results bring together the univariate and MVPA literature and demonstrate that parietal cortex plays a central role in VSTM information storage. Early visual areas, however, are unlikely to be essential for memory storage, and may reflect cognitive processes, such as visual rehearsal or imagery, that are brought online, particularly under low visual processing loads, to support the maintenance of memory representations.

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Tuesday AM

Perception and action: Reaching and grasping

Tuesday, May 20, 10:45 am - 12:30 pm
Talk Session, Talk Room 1
Moderator: Fulvio Domini

52.11, *10:45 am* **A preference to adjust where** rather than when to hit a moving target Eli Brenner[1](e.brenner@fbw.vu.nl), Jeroen BJ Smeets[1]; [1]Faculty of Human Movement Sciences, Research Institute MOVE, VU University Amsterdam

Moving objects can be intercepted at various places at different times. To successfully intercept such objects one must select appropriate combinations of time and place. If, while moving towards the object, one notices that one is going to arrive slightly too early, or equivalently that one is aiming slightly too far ahead of the object, one could slow down, aim less far ahead of the object, or both. Similarly, if one notices that one is going to arrive slightly too late, one could speed up or aim further ahead. Do people adjust the place, the time or both when they detect that they are going to miss a moving target? Since there is normally no way of telling when people notice that they need to adjust their movements, we introduced errors artificially. The task was to tap virtual targets that were moving to the right across a screen with one's index finger. On some trials, the target jumped to the left or right, or closer or further from the finger's starting point, as soon as the finger started moving. Participants adjusted the position of the tap, leaving the timing unaffected. When participants were explicitly instructed to intercept the target at a specified position on the screen, they adjusted their timing as requested, tapping later for leftward target jumps and earlier for rightward target jumps. Comparing the velocity profiles revealed that participants adjusted the position that they were aiming for considerably faster than they did the timing of the tap, even when both involved speeding up or slowing down their finger's movement. This difference in latency could underlie the preference to adjust where rather than when to hit the target when no further instruction is given.

52.12, *11:00 am* **Adaptation to visual feedback delays in predictable manual tracking recalibrates perceived simultaneity** Marieke Rohde[1,2](marieke.rohde@uni-bielefeld.de), Loes van Dam[1,2], Marc Ernst[1,2]; [1]Department of Cognitive Neuroscience, University of Bielefeld, [2]Center of Excellence CITEC - Cognitive Interaction Technology, University of Bielefeld

Humans effortlessly compensate for feedback delays due to neural processing and physical transmission times in closed-loop motor control. With training, they can also adapt to additional latencies but the nature of adaptation is unclear. Three alternative processes have been suggested: (1) control stabilization by decreased control gain (2) spatial prediction of control signal (3) temporal recalibration of motor prediction (forward model). Only temporal recalibration can be expected to also recalibrate time perception (shift in perceived simultaneity). At present, most of the evidence points towards the first two options. Our hypothesis is that instead all three processes can occur and depend on the nature of the task. Particularly, we hypothesize that temporal recalibration is only possible with continuous feedback and a predictable control signal. To test this hypothesis, we trained participants with a 200ms feedback delay in a visually-guided manual-tracking task, varying the predictability of the reference signal between conditions, but keeping reference motion and delayed visual feedback constant. In Experiment 1, we focused on motor behavior (spatial error, temporal error, and spectral power of movement). We observed that only predictable training brings about negative aftereffects in all three measures. This combination of negative aftereffects indicates temporal recalibration of the forward model. By contrast, the results from unpredictable training indicate compensation by decreased control gain. We then tested whether delay adaptation in tracking also transfers to a perceptual task. After predictable but not unpredictable delay adaptation, we observed a 30ms shift of perceived simultaneity in a synchronization task (Experiment 2) and 38ms shift in an interval estimation task (Experiment 3). These results show that temporal recalibration of behavior and time perception is possible with a predictable control signal. The decreased control gain after unpredictable training confirms that different adaptive processes are evoked depending on the task.

Acknowledgement: This research was funded by the Deutsche Forschungsgemeinschaft (DFG), grant ELAPS: embodied latency adaptation and the perception of simultaneity

52.13, *11:15 am* **Visual on-line control of grasping movements** Robert Volcic[1](robert.volcic@iit.it), Fulvio Domini[1,2]; [1]Center for Neuroscience and Cognitive Systems@UniTn, Istituto Italiano di Tecnologia, [2]Department of Cognitive, Linguistic & Psychological Sciences, Brown University

Seeing your hand while grasping self-evidently affects the action in progress. Observers could potentially use visual feedback to adjust the trajectory of the moving limb, or to shape the posture of the hand and fingers, or both. Here, we investigated how the visually sensed finger grip aperture influences the on-line control of grasping movements. We used a dynamic perturbation method that altered the position of the visual feedback relative to the actual position of the thumb and index fingertips to virtually increase/decrease the actual grip aperture. Importantly, the virtual grip aperture was smoothly altered only when the actual grip aperture was larger than the size of the object to be grasped. In this way, the perturbation was present during most of the movement, but vanished the moment the fingers contacted the object. Subjects performed grasping movements in a virtual environment with haptic feedback. Visual feedback of the hand was provided by rendering virtual spheres representing the subject's thumb and index fingertips. The virtual grip aperture was smaller than, larger than, or equal to the actual grip aperture. These perturbations were presented in a randomized order to prevent adaptation. Despite the substantial changes of the virtual grip aperture, the actual grip aperture was unaffected. However, we found that the virtual grip aperture modulated specific aspects of reach and grasp dynamics. The smaller the virtual grip aperture, the earlier the peak wrist deceleration occurred, the later the grip aperture reached its maximum, and, the later the fingers enclosed the object. Moreover, the virtual grip aperture affected fine-tuned adjustments of the hand position when in the immediate vicinity of the object. These findings provide evidence that the visual feedback of the hand is more involved in the direct control of the moving limb, than in the control of the grip aperture.

52.14, *11:30 am* **Getting a grip on different materials** Vivian C. Paulun[1](Vivian.C.Paulun@psychol.uni-giessen.de), Karl R. Gegenfurtner[1], Melvyn A. Goodale[2], Roland W. Fleming[1]; [1]Department of Experimental Psychology, University of Giessen, [2]The Brain and Mind Institute, The University of Western Ontario

A precision grip of index finger and thumb is often used to interact with objects in our environment. To successfully accomplish this everyday task we adapt our grip depending on various extrinsic and intrinsic properties of the object to be grasped. For example, the grasping movement needs to be adjusted if we want to grasp a wooden spoon or a wet bar of soap to provide a stable grip without the object rotating or falling. This adjustment not only depends on object features like shape or size, but presumably also on the visually perceived material the object is made of. We let our participants grasp cylinders of the same size (height: 10 cm, diameter: 2.5 cm) but different materials, i.e. foam, wood and brass as well as an additional brass cylinder covered with vaseline to make it slippery. These stimuli laid on their long side at six different angles with respect to the participants (0°, i.e. horizontally, 30°, 60°, 90°, 120°, 150° rotated counterclockwise). The task was to grasp, lift and carry the target objects to a goal position and place them there. We found that timing of the movement towards and while holding the cylinders was influenced by its material properties. Reaction time, movement duration to the object, handling and transport duration were on average longer for the slippery cylinder covered with vaseline. Object orientation appeared to primarily affect spatial characteristics of the movement like position and orientation of the grasp axis. However, these spatial effects were modulated by the material of the target object. Taken together our results imply that the timing and positioning of the precision grip depends on the object's visually perceived material properties.

Acknowledgement: DFG-IRTG 1901: The Brain in Action

52.15, *11:45 am* **Visual Feedforward Grasping and Motor Adaptation to Actual Target Width in Visual Form Agnosic Patient DF** Robert L. Whitwell[1,2,3](rwhitwell@hotmail.com), A. David Milner[4], Cristiana Cavina-Pratesi[4], Masih Barat[1], Caitlin M. Byrne[1,2], Melvyn A. Goodale[1,2]; [1]The Department of Psychology, The University of Western Ontario, London, ON, Canada, [2]The Brain and Mind Institute, The University of Western Ontario, London, ON, Canada, [3]The Graduate Program in Neuroscience, The University of Western Ontario, London, ON, Canada, [4]Department of Psychology, Durham University, Durham, United Kingdom

Patient DF, who developed visual form agnosia following ventral stream damage, configures her hand in-flight to match the geometric properties of novel objects when picking them up, despite her inability to use these same properties to explicitly differentiate amongst these objects. We have proposed that her spared grasping is mediated by a feedforward-visuomotor

 See page 3 for Abstract Numbering System

system within the posterior parietal lobe. Another interpretation, however, proposes that her dissociated performance is due to the bimodal nature of grasps compared to unimodal visual perceptual judgments. According to this new account, DF uses haptic feedback from touching the goal objects to calibrate visual egocentric cues about the finger-contact positions on the object surfaces. Thus, the 'perception-action' dissociation could be an artifact of the presence or absence of visual-haptic calibration. To test this 'calibration hypothesis' directly, we presented DF with a grasping task in which the visual size of the target varied from trial to trial while its actual size remained the same. In so doing, we uncoupled haptic and visual input, disrupting visual-haptic calibration. According to the calibration hypothesis, DF's grasps should no longer reflect the visual size of the goal objects. Contrary to this prediction, however, DF continued to scale her grip aperture to the visual sizes of the targets. Furthermore, providing haptic feedback about perceptual judgments of visual size did not improve her chance performance. Finally, we also show that DF does not require online visual feedback to scale her grip aperture to target size. Together, these findings strengthen the notion that DF's spared grasps are driven by visual-feedforward processing. They also suggest that tactile contact with an object keeps the visuomotor dorsal stream engaged, preventing the grasps from defaulting to pantomimes. The need for actions to have a tangible endpoint provides an important modification of the Two Visual Systems hypothesis.

Acknowledgement: NSERC, Wolfson Research Institute for Health and Wellbeing

52.16, *12:00 pm* **Neurophysiological investigations of speed-accuracy tradeoff** Richard Heitz[1,2,3](richard.p.heitz@vanderbilt.edu), Jeffrey Schall[1,2,3]; [1]Department of Psychology, Vanderbilt University, [2]Center for Integrative and Cognitive Neuroscience, Vanderbilt University, [3]Vanderbilt Vision Research Center

Agents must balance speed of responding and accuracy of choosing to suit current goals and environmental demands. This speed-accuracy tradeoff is a fundamental phenomenon in behavioral science, and is pervasive across multiple task domains and species. Though it is exceptionally well characterized behaviorally and computationally, the underlying neural mechanisms have been elusive. To address this, I designed a nonhuman primate model of speed-accuracy tradeoff: Monkeys were trained to respond at 3 levels of speed or accuracy emphasis during a saccade visual search task. Emphasis conditions were cued by the color of a fixation point. Meanwhile, I recorded single-unit responses in frontal eye field, supplementary eye field, and superior colliculus. Here, I will demonstrate that the speed-accuracy tradeoff entails both local and global adjustments of neural activity across the brain. Briefly, the effect of speed/accuracy emphasis on perceptual processing appears global. Visually-responsive neurons in prefrontal cortex, medial frontal cortex, and tectum maintain an elevated background firing rate and become more responsive to identical perceptual input when under speed stress than accuracy stress. The form and magnitude of these adjustments are equivalent across brain sites. In contrast, the effect of speed/accuracy emphasis on movement-related responses is more complex, and differs markedly (but consistently) between brain regions. These data make clear that the speed-accuracy tradeoff is a multifaceted phenomenon involving several distinct adjustments in multiple brain areas.

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52.17, *12:15 pm* **How does sensorimotor control change with age? A comparison of visual and pointing performance in older and younger people** Anna Ma-Wyatt[1](anna.mawyatt@adelaide.edu.au), Jessica O'Rielly[1], Reuben Pucek[1], Adam Kane[1], Preeti Verghese[2], Laura Walker[2]; [1]School of Psychology, University of Adelaide, Adelaide, Australia, [2]The Smith-Kettlewell Eye Research Institute, San Francisco, USA

Introduction: Age-related changes in goal-directed movements may be due to sensory-related or motor-related decline or may also be affected by more generalised slowing of neural processing. There is currently no model that can account for age-related changes to sensorimotor control and its effects on goal-directed movements. We investigated use of visual information for planning and online updating of a rapid movement task. The goal of these experiments was to quantify differences in performance on visual and sensorimotor tasks between older and younger observers. Methods: Older (age range 60-70) and younger (age range: 20-30) observers were screened for visual and motor deficits before testing. We measured visual localisation performance and compared it to pointing performance for targets presented for 100ms or on until touch. We tested two different stimulus durations to investigate how visual information about target location could be used to plan and update movements online. We also used a two step online correction task to further quantify changes in rapid online integration. Results: Although visual localisation was comparable between groups, pointing precision to targets presented for 100ms and on until touch was significantly lower for older people. Movement times for older observers were longer, consistent with previous work. In the two step task, older observers showed a reduced ability to update their movements and longer overall movement times. When forced to reach under time pressure, older observers showed lower accuracy and decreased precision compared to younger observers. Conclusion: Older people show decreased sensorimotor control compared to younger people. Visual performance was comparable across older and younger people, while movements were generally slower. Altogether, results suggest that declines in pointing performance with age reflect changes to sensorimotor integration, particularly online integration of visual information. The implications for current models of sensorimotor control will be discussed.

Object recognition: Neural mechanisms 2

Tuesday, May 20, 10:45 am - 12:30 pm
Talk Session, Talk Room 2
Moderator: Brendan Ritchie

52.21, *10:45 am* **Rapid extraction of category-specific shape statistics: Evidence from event-related potentials** Bria L. Long[1](brialong@fas.harvard.edu), Viola S. Störmer[1], George A. Alvarez[1]; [1]Department of Psychology, Harvard University

During visual search, observers analyze target-distractor similarity rapidly, allocating attention to the most informative part of the display. The difficulty of target selection is indexed by the N2pc, an early, lateralized event-related potential (ERP) component (Luck & Hillyard, 1994). Here, we examined how target selection is modulated by distractor similarity of real-world categories. Observers searched for an object that was presented either among five distractors of the same category (uniform displays) or of a different category (mixed displays). Stimuli were either animals or inanimate objects; these categories were equalized across factors already known to influence visual search for simple stimuli, including low-level properties (e.g., luminance, contrast, power at different spatial frequencies and orientations, size, etc.) in addition to familiarity and typicality. Observers' accuracy was higher on mixed vs. uniform trials, indicating a more efficient search process on mixed displays. To investigate the neural underpinnings of this performance difference, ERPs were recorded from posterior electrode sites (PO7/PO8), where an enlarged negativity contralateral to target location was found from 180 to 300ms after display onset – the N2pc. The N2pc amplitude was greater for uniform vs. mixed displays ($F(1, 8) = 5.89$, $p < .05$), suggesting that more attentional resources were allocated on uniform relative to mixed trials, presumably to resolve the increased similarity between same-category targets and distractors. As we controlled stimuli for a wide range of low-level feature dimensions, these results suggest that differences in mid-level shape features between animals and inanimate objects can modulate rapid attentional allocation during search.

Acknowledgement: V.S.S. was funded by the Marie Curie fellowship (EU Grant PIOF-GA-2012-329920).

52.22, *11:00 am* **The time course of three-dimensional object recognition in human vision: An ERP study** Zoe J. Oliver[1](psp247@bangor.ac.uk), Mark V. Roberts[1], Alan J. Pegna[2], Charles Leek[1]; [1]School of Psychology, Bangor University, Bangor, UK, [2]Geneva University Hospital, Geneva, Switzerland

One of the great mysteries of the human brain is how we are able to perceive and identify three-dimensional (3D) objects rapidly and accurately despite variability in viewing conditions and sensory input. While some kinds of image classification have been reported to occur as quickly as 100-150ms post-stimulus onset (Thorpe et al., 1996, Nature), we know relatively little about the time course of different perceptual processes involved in object recognition. We investigated these issues using 1000 Hz, 64 channel event-related potentials (ERPs). Participants completed a perceptual matching task in which they had to make shape equivalence judgments about two sequentially presented 3D surface rendered multi-part novel objects. Trials could either contain two identical objects (differing only in scale to eliminate pixel overlap), or two different objects. There were three types of different object trials: Stimulus pairs could share volumetric parts but differ in spatial configuration (Same parts/Different configuration), contain different volumetric parts but share spatial configuration (Different parts/Same configuration) or share neither parts or spatial configuration. Analyses of the ERP waveforms showed no differences between conditions on the early P1 component – indicating that the conditions were well-matched in terms

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of low-level image properties. In contrast, we found evidence of differential sensitivity to volumetric part and spatial configuration overlap in the different response trials on posterior electrodes. This was reflected in amplitude modulations of negative deflections on the N1 component between different object conditions approximately 170ms post-stimulus onset. These differences suggest an early perceptual sensitivity to shared spatial configuration but not local part structure. We propose that this pattern of results is consistent with the operation of two parallel processes during shape perception involving a fast, low-spatial frequency, analysis of global shape configuration, and a slow, high spatial frequency, analysis of local part structure.

52.23, *11:15 am* **Representational geometry measures predict categorisation speed for particular visual objects** Ian Charest[1](ian.charest@mrc-cbu.cam.ac.uk), Thomas A. Carlson[2], Nikolaus Kriegeskorte[1]; [1]Medical Research Council – Cognition and Brain Sciences Unit, Cambridge, UK, [2]Department of Cognitive Sciences, Macquarie University, Sydney, Australia

The choice reaction time reflects the rate of accumulation of sensory evidence. For categorisation, Carlson et al. (2013) showed that an animate object can be more rapidly recognised as such when it is further away from the animate-inanimate boundary in human-inferior-temporal (hIT) representational space (as reflected in fMRI data from Kriegeskorte et al. 2008). Here, we extend these results by considering multiple category dichotomies, multiple measures of representational geometry, and multiple ventral-stream brain regions. Subjects categorised objects according to four dichotomies: animate vs. inanimate; face vs. body; human vs. animal face; natural vs. artificial inanimate object. We examined a range of representational-geometry measures, including each object's representational centrality (i.e. its average distance to other members of its own category), its distinctness from the other category (i.e. its average distance to members of the other category), and the proportion of category peers within its local neighbourhood. We assessed whether these measures predict subjects' reaction times for particular objects using Spearman's rank correlation (ρ, computed within each subject and then averaged across subjects) combined with non-parametric inference and control of the false-discovery rate. For most tasks and ventral-stream brain regions, an object's within-category representational centrality was the best predictor of reaction time among the tested representational-geometry measures. Three example results are: (1) The hIT centrality predicted reaction time for animate vs. inanimate categorisation ($\rho = 0.2$; $p<0.0001$). (2) Centrality in the fusiform face area predicted reaction time for human vs. animal face categorisation ($\rho = 0.2$; $p <0.01$). (3) Centrality in the parahippocampal place area predicted reaction time for natural vs. artificial inanimate categorisation ($\rho = .29$; $p <0.001$). Our results suggest that the representational geometry as reflected in human fMRI can explain aspects of the computational processes leading to a decision about a particular visual object.

Acknowledgement: Medical Research Council, European Research Council

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52.24, *11:30 am* **Selectivity for non-accidental properties emerges from learning object transformation sequences** Sarah Parker[1](sarah_m_parker@brown.edu), David Reichert[1], Thomas Serre[1]; [1]Department of Cognitive, Linguistic and Psychological Sciences, Brown University

Behavioral and electrophysiology studies of shape processing have demonstrated greater sensitivity to differences in non-accidental properties (NAPs) than metric properties (MPs; see Biederman, 2007 for review). NAPs correspond to image properties that are invariant to changes in out-of-plane rotation (e.g., straight vs. curved contours) and are distinguished from metric properties (MPs) that can change continuously with variations over depth orientation (e.g., aspect ratio, degree of curvature, etc). Previous work has shown that such sensitivity is incompatible with hierarchical models of object recognition such as HMAX (Riesenhuber & Poggio, 1999; Serre et al, 2007), which assume that shape processing is based on broadly tuned neuronal populations with distributed symmetric bell-shaped tuning: Shape-tuned units in these models are modulated at least as much by differences in MPs as in NAPs (Amir, Biederman & Hayworth, 2012). Here we test the hypothesis that simple mechanisms for learning transformation sequences may increase sensitivity to differences in NAPs vs. MPs in HMAX. We created a database of video sequences of objects rotated in depth in an attempt to mimic sequences viewed during object manipulation by infants during early developmental stages. We adapted a version of slow feature analysis (Wiskott & Sejnowski, 2002) to learning in HMAX: Unit responses in intermediate processing stages were scaled according to how stable they remained during the presentation of common objects undergoing various transformations. We show that this simple learning rule leads to shape tuning in higher stages with greater sensitivity to differences in NAPs vs. MPs consistent with monkey IT data (Kayaert et al, 2003). Overall we propose a simple learning mechanism to extend hierarchical models of object recognition to exhibit greater sensitivity for NAPs than MPs, as observed both behaviorally and electrophysiologically. Our results suggest that greater sensitivity for NAPs may result from unsupervised learning mechanisms from transformation sequences of common objects.

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52.25, *11:45 am* **Emerging Representational Geometry for Objects Predicts Reaction Time for Categorization** J. Brendan Ritchie[1,2,4](britchie@umd.edu), David Tovar[3], Thomas Carlson[1,2]; [1]Department of Cognitive Science, Macquarie University, [2]ARC Centre of Excellence in Cognition and its Disorders, Macquarie University, [3]School of Medicine, Vanderbilt University, [4]Department of Philosophy, University of Maryland, College Park

Recent human and primate neurophysiological studies have characterized a representational geometry for visual objects in inferior temporal cortex (ITC), in which individual exemplars are both discriminable and cluster based on object category (e.g. faces and body parts). Two outstanding questions are: when does this representational geometry emerge; and how does the structure of the geometry relate to behavior? Recent findings have made important progress on these questions. First, multivariate pattern analyses in conjunction with Magnetoencephalography (MEG decoding) have described the emerging representational geometry of objects in high temporal resolution. And second, using human fMRI, it has been shown that reaction times (RT) for object categorization are predicted by the structure of ITC's representational geometry. We build on these findings and show RTs for object categorization can be predicted by the geometry of the brain's representation of objects shortly after the presentation of a visual stimulus. In the present study, participants categorized as quickly and accurately as possible images of 12 animate and 12 inanimate object exemplars. Time-resolved MEG decoding was used to reconstruct the brain's representational geometry of the exemplars on a moment-to-moment basis (20 ms resolution). Using linear discriminate analysis, for each time period we computed a discriminate boundary through the representational geometry that separated animate and inanimate exemplars, and then calculated the distance of individual exemplar representations from the boundary. Classical signal detection theory (SDT) predicts a negative correlation between distance from the boundary and RT. In accordance with the prediction of SDT, and previous findings using fMRI, we found that distance from the decision boundary negatively correlated with RTs beginning at 200 post-stimulus onset. Our results reveal when the structure of the brain's emerging representational geometry for objects predicts behavioral RTs, supporting the contention that "representing" is a core aspect of decision-making for categorization.

52.26, *12:00 pm* **Large-scale Characterization of a Universal and Compact Visual Perceptual Space** Ha Hong[1,2](hahong84@gmail.com), Ethan Solomon[1,3], Dan Yamins[1], James DiCarlo[1]; [1]Department of Brain and Cognitive Sciences and McGovern Institute for Brain Research, MIT, Cambridge, MA, [2]Harvard-MIT Division of Health Sciences and Technology, MIT, Cambridge, MA, [3]Perelman School of Medicine, University of Pennsylvania, Philadelphia, PA

Many visual psychophysics experiments hypothesize a perceptual space whose axes encode key features on which judgements are made. We characterized human perceptual space for an image set with 64,000 images of 64 objects, shown with differing positions, sizes, poses, and backgrounds. We performed online psychophysical experiments involving 703 observers, obtaining confusion matrices for 2016 two-alternative forced-choice (2AFC) pairwise object identification tasks. Generalizing Getty (1979) and Ashby (1991), we hypothesized that: (1) for each object, multiple image instances sample a Gaussian pointcloud in perceptual space; and (2) identity decisions could be modeled with distance-based classifiers applied to these Gaussian clouds. The dimension, locations, and spreads of the Gaussians were then chosen to be consistent with experimentally observed confusions. The resulting representation almost perfectly predicts confusions on held-out images and is stable to the addition of new objects. It also generalizes to visual tasks well beyond the original 2AFC task, predicting human responses for: (1) 8-way AFC recognition tasks, (2) ratings of objects with adjectives (e.g. "rectangular", "cuddly"), and (3) subjective similarity judgements between objects. The representation scales efficiently with object number, requiring ~47 dimensions to encode 10,000 distinct objects (Biederman, 1987). Given the scale and precision of the dataset, we were able to make direct comparisons to neural data. We found that the object layout in the inferred human perceptual space correlated highly with those from the neural population representation measured in Inferior Temporal

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(IT) cortex. Taken together, these results suggest that the human brain produces a visual perceptual space that is both universal (underlies behavior for many different tasks) and compact (requires few dimensions to represent many entities). We anticipate extensions of this method will further bridge neural and perceptual observations, and help characterize how interventions (e.g., learning and attention) modify perceptual representations.

52.27, *12:15 pm* **Selective Metamorphopsia for Letters and Digits**

Michael McCloskey[1](michael.mccloskey@jhu.edu), Teresa Schubert[1], David Rothlein[1], Brenda Rapp[1], Diane Slonim[2], Karen Van Den Heuvel[2]; [1]Cognitive Science Department, Johns Hopkins University, [2]Westchester Institute for Human Development

We describe a remarkable perceptual deficit in which letters and digits appear so blurred or distorted as to be unidentifiable, yet other visual stimuli are perceived normally. MTS, a 13-year-old girl, suffered a cerebral hemorrhage at age 10. Reading at grade level prior to the stroke, she was completely alexic thereafter. MTS is unable to identify, describe, or copy letters or digits, reporting that she sees only unrecognizable blurs. In contrast she is intact in identifying and copying shapes, line drawings, and non-alphanumeric symbols (e.g., #, %), ruling out a low-level perceptual impairment, and demonstrating the category specificity of the deficit. We interpret the deficit in terms of impaired feedback from category-specific character recognition processes to earlier levels of visual representation. According to some theorists, feedback is necessary for visual awareness, and shapes the perceptual experience. Disordered feedback from letter and digit recognition processes could therefore lead to disordered perception of stimulus characters. This interpretation also accounts for results we presented previously (VSS 2012) for a patient showing selective perceptual distortion for digits. Remarkably, MTS is able to perceive and identify letters and digits in some non-standard fonts—for example, fonts created from drawings of objects, or fonts with gaps or strikethrough lines that disrupt stroke contours. She can also identify letters and digits when she observes writing motions. These results are consistent with recent proposals that characters may be identified via multiple neural pathways: The stimuli MTS can identify may recruit neural mechanisms (e.g., object recognition or motion perception mechanisms) different from those that process standard characters, and so may avoid triggering pathological feedback. The results with non-standard characters provided a basis for remediating MTS's reading disorder: After being entirely unable to read for nearly two years, she now reads successfully on a laptop with a double-strikethrough font installed.

Acknowledgement: Johns Hopkins University Science of Learning Institute

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Tuesday Morning Posters

Visual search: Attention

Tuesday, May 20, 8:30 am - 12:30 pm
Poster Session, Jacaranda Hall

53.301 Winter is coming: How humans forage in a temporally structured environment

Jinxia Zhang[1,2](jxzhang.china@gmail.com), Daryl Fougnie[2], Xue Gong[3], George Alvarez[4], Jeremy Wolfe[2,5]; [1]Nanjing University of Science and Technology, [2]Brigham and Women's Hospital, [3]Wheaton college, [4]Harvard University, [5]Harvard Medical School

Much is known about how individuals search visual displays for targets, but relatively little about how they find multiple targets across multiple displays (foraging tasks). How long should you spend at each raspberry bush before moving in order to collect as many berries as possible? Classic optimal foraging theories suggest that an observer leaves when current intake drops below the average rate. This theory is typically tested in random or uniform environments. However, the real world has structure—events close in time are likely to be similar. Here we explored whether temporal structure influences foraging behavior by creating 'seasons'. Does it matter if winter is coming and the next bush is reliably worse than the last? In our task, 35 participants were asked to pick "good" berries from bushes. Bush quality varied from 8-32 good berries out of 40. Good berries could be defined by color (redder-better) or only by auditory feedback after picking. Participants were asked to pick a fixed number of berries (1500 with color cue; 1000 without color cue). Bush quality could be structured - rising and falling systematically or random. Participants were informed about color but not about temporal structure. In the structured condition, observers picked more berries from the current bush when quality was falling ($p<.001$ with color cue; $p<0.005$ without color cue) showing that foraging behavior is affected by temporal context. We replicated these results in an unguided letter search task with displays having 0-10 Ts among 54-64 Ls. If the number of Ts varied systematically, observers again stayed longer when patch quality was falling ($p<.001$); stocking up for winter or enjoying the last of summer. Taken together, these results show that human foragers make use of more information about the structure of the world than expected by classical "optimal" foraging models.

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53.302 Visual search is influenced by 3D spatial layout

Nonie Finlayson[1,2](nonie.j@gmail.com), Philip Grove[1]; [1]School of Psychology, The University of Queensland, [2]Department of Psychology, The Ohio State University

Many activities necessitate the deployment of attention to specific distances and directions in our three-dimensional (3D) environment. However, most research examining how attention is deployed is conducted with two dimensional (2D) computer displays, leaving a large gap in our understanding of the deployment of attention in 3D space. Here we report how each of four parameters of 3D visual space influence visual search performance. These include the 3D volume of the array that search items are displayed in, the distance in depth between search items, the number of depth planes that distractors are arranged into, and the target position in depth relative to the distractors. Using a search task, we demonstrate that visual search performance depends on both 3D volume and relative target position in depth. Target selection was faster in smaller 3D search volumes, and targets were found faster when located nearer the front of the display relative to distractors. Neither the distance in depth of a target from the initial point of fixation nor the number of depth planes that items were arranged into affected search performance. These data demonstrate an asymmetrical preference for targets in the front of a display unique to 3D search, and highlight the importance of relative position in depth compared to the absolute depth of a target.

53.303 Workload Capacity Analysis of Stereoscopic Pop-Out in Visual Search

Joseph Houpt[1](joseph.houpt@wright.edu), Leslie Blaha[2], Elizabeth Fox[1]; [1]Department of Psychology, Wright State University, [2]711 HPW/RHCV, United States Air Force Research Laboratory

Stereo depth cues can potentially provide a salient source of information to aid visual decision making. For example, in a visual search paradigm, stereo depth cues can literally cause part of an image to "pop out" at the observer (crossed binocular disparity cues). While some research has examined the mechanisms supporting search across various depth planes (Finlayson, et al., 2013), minimal research has examined the mechanisms engaged when stereo depth itself is the search target. The goal of this project was to examine the human information processing characteristics of stereo depth as a source of target information. We utilized the powerful measures and experimental methodology of Systems Factorial Technology (SFT; Townsend & Nozawa, 1995) to assess the workload capacity characteristics of stereo depth cues in a visual search paradigm. Standard group-level mean response time analyses indicated a nearly flat slope of mean target present response time as a function of distractor set size (although significantly nonzero) and a much larger slope of mean target absent response times. This pattern is characteristic of perceptual "pop-out" in visual search (Wolfe, 1998), and confirms that stimulus stereo disparity results in visual search "pop-out" effects. Furthermore, larger stereo disparity led to faster responses. Interestingly, workload capacity analyses at the individual participant level indicated worse than standard parallel performance with a filled array of distractors for nearly all participants. Participants fell into two groups with a sparser placement of distractors: most participants were still worse than standard parallel (limited capacity), but some were much better (super capacity). These results suggest that stereo pop-out visual search may utilize processing mechanisms that differ from a standard parallel architecture, and this architecture is influenced by the organization of the search display and varies across individuals. Distribution A: Approved for public release; distribution unlimited. 88ABW Cleared 12/02/2013; 88ABW-2013-5017.

53.304 Searching for the right word: Hybrid visual and memory search for words

Sage E.P. Boettcher[1](sboettcher@partners.org), Jeremy M. Wolfe[1,2]; [1]Brigham & Women's Hospital, [2]Harvard Medical School

In "Hybrid Search" (Wolfe 2012) observers search through visual space for any of multiple targets held in memory. With photorealistic objects as stimuli, response times (RTs) increase linearly with the visual set size and logarithmically with memory set size even when over 100 items are committed to memory. It is well established that pictures of objects are particularly easy to memorize (Brady, Konkle, Alvarez, & Olivia, 2008). Would hybrid search performance be similar if the targets were words or phrases where word order can be important and where the processes of memorization might be different? In Experiment One, observers memorized 2, 4, 8, or 16 words in 4 different blocks. After passing a memory test, confirming memorization of the list, observers searched for these words in visual displays containing 2 to 16 words. Replicating Wolfe(2012), RTs increased linearly with the visual set size and logarithmically with the length of the word list. The word lists of Experiment One were random. In Experiment Two, words were drawn from phrases that observers reported knowing by heart (E.G. "London Bridge is falling down"). Observers were asked to provide four phrases ranging in length from 2 words to a phrase of no less than 20 words (range 21-86). Words longer than 2 characters from the phrase constituted the target list. Distractor words were matched for length and frequency. Even with these strongly ordered lists, results again replicated the curvilinear function of memory set size seen in hybrid search. Especially with memorized phrases, one might expect serial position effects; perhaps reducing RTs for the first (primacy) and/or last (recency) members of a list (Atkinson & Shiffrin 1968; Murdock, 1962). Surprisingly we showed no reliable effects of word order. Thus, in "London Bridge is falling down.", "London" and "down" are found no faster than "falling".

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53.305 Updating for free? Span and Updating tasks modulate Visual Search in a similar manner

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Many theories in cognitive psychology have proposed that working memory (WM) plays a central role in visual search (VS). Tasks evaluating the role of WM in VS have generally used dual-task paradigms where VS tasks are performed with or without a WM load that is passively maintained. Under these circumstances, previous research has found that the VS task is slowed. Furthermore, search efficiency also decreased under some circumstances. While passive WM tasks appear to require resources to maintain information in WM, it is unclear how VS would be influenced by an updating task that required more continuous processes of encoding or maintenance. We contrasted VS performance with a span

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task load or an updating load. In both tasks, we asked observers to perform a typical T among Ls search task. A single object was displayed in the center of each VS display. In the span task, observers were asked to hold 1-4 objects in memory. During every VS trial observers had to determine whether the object in the VS display was one of the objects maintained in memory. After twelve trials, they had to report how many times an object from their memory set appeared during the preceding VS trials. In the updating task, observers had to determine how many times the central object was repeated in an Nback task. After every twelve trials participants were asked to answer how many times a repetition occurred. We observed an additive cost of the load for both span and updating tasks but no evidence for a decrease in search efficiency in any task. Both span and updating task appear to modulate VS processes in a similar manner.

53.306 **Nonlinear effects of target-distractor feature sharing in triple conjunction visual search** Maria Nordfang[1,2](maria.nordfang@psy.ku.dk), Jeremy M. Wolfe[1]; [1]Brigham & Women's Hospital, Harvard Medical School, [2]University of Copenhagen

Suppose you are searching for one of the 27 stimuli created by the conjunctions of three colors, three shapes, and three orientations (say your target is a red, vertical, rectangle, leaving the remaining 26 stimuli as possible distractors). Models like Feature Integration and Guided Search predict that the efficiency of that triple conjunction search will depend on the features shared by the distractors and the target, not on the specific conjunctions of these features. However, conjunction effects have been found (e.g., Wolfe, 2010). We propose that a primary cause of this effect is a non-linearity in the effects of target-distractor feature sharing. A triple conjunction target can share zero, one, or two features with any distractor. In Experiment 1, we varied the number of features the distractors shared with the target. We found that compared to a baseline where all distractors share one feature with the target, the cost of sharing two features is greater than the benefit of sharing zero. In Experiment 2, we extended this nonlinearity to six-fold conjunctions. In Experiment 3, distractors always shared one feature on average with the target but, in some displays, distractors shared zero, one, or two features while in other displays all distractors shared one feature. This allowed us to keep the distribution of individual features constant. Because the cost of sharing two is greater than the benefit of sharing zero, the Share012 condition is slower than the AllShare1 condition. In Experiment 4, with brief exposures (110 and 200 msec), we found a subsidiary effect of grouping. Share012 conditions were slower if they contained 12 distinct distractor types compared to three types. These Sharing and Grouping effects are not predicted by previous accounts of GS; however, they can be accommodated in a GS framework.

53.307 **When Does the Aardvark Move to the Next Anthill? Foraging search with moving targets** Matthew S. Cain[1,2](mcain@partners.org), Sage E. P. Boettcher[1], Jeremy M. Wolfe[1,2]; [1]Brigham & Women's Hospital, [2]Harvard Medical School

A longstanding question in visual search is when to stop searching in one display and move to the next one. This complex question becomes more complex as the number of potential targets increases, and the task begins to resemble the ecological problem of foraging (Cain, Vul, Clark, & Mitroff, 2012; Wolfe, 2013). Work to date has involved static images, like schematic berry bushes. In humans, such displays encourage systematic strategies such as 'reading' the display left-right, top-bottom. To thwart systematicity, we had all the items on the screen move continuously, like schematic anthills. This successfully induced participants to use color-guided search rather than systematic spatial search. The value of 'ants' varied with their color; the greener the better. In one block, all ants had positive value. In another block, the worst ants had negative value, while the expected value of the entire patch remained the same across conditions. Overall, searchers started by clicking on the greenest, most valuable targets and clicked on less-green items as the trial progressed. Consequently, the rate of return dropped as observers picked ants in one anthill. On average, participants clicked on just under half the items in each display, in line with the predictions of optimal foraging theory that searchers should maximize their rate of point accumulation rather than exhaustively collecting all the target ants, even when all ants had positive value. Participants clicked on fewer and greener items when losses were more possible than when only gains were available. This pattern became more pronounced with increasing set sizes. This more conservative, loss-averse strategy leads to an overall reduction in the efficiency of point accumulation that may not be predicted by standard optimal foraging models. Overall, these anthill findings suggest that the previously-described patterns of human foraging behavior are not by-products of a spatial foraging strategy.
Acknowledgement: NIH EY017001

53.308 **Enhanced filtering by motion in visual search: The case of action video-game play** Kevin Dent[1](kdent@essex.ac.uk); [1]Department of Psychology, University of Essex

Movement is a powerful cue for the guidance of attention. Search through moving and stationary objects may be restricted to the moving group. However, it is sometimes difficult to guide search by movement independently of other features in the display. Thus when a moving target differs in colour from moving distractors but shares colour with static distractors, it becomes difficult to find (Dent, Braithwaite, & Humphreys, 2011). This finding has been attributed to the target inheriting low attentional priority from the linked static items. The current study investigated how experience with action video-games impacts the ability to use movement independently of colour to guide search. In the motion-segmentation condition participants searched for a moving target (Z or N) amongst moving O and stationary Z and N distractors. The moving and stationary distractors were always coloured differently. Critically the target shared colour with either the moving or stationary distractors. This motion-segmentation condition was compared against a baseline presenting only the moving items. Experiment 1 compared action video-game players against non-players. While the non-players showed a cost when the target shared colour with the static distractors in the motion-segmentation condition, the video-game players did not. Experiment 2 trained two groups of participants to play either a puzzle game (Tetris) or an action game (Halo) for 14 hours. While both groups of participants were initially slower to identify targets sharing colour with the static distractors, the effect was eliminated by action video-game training, with only the Tetris players continuing to show this effect post-training. Action video-game play thus appears to enhance the ability to use motion independently of colour to filter out distractors in search. Dent, K., Humphreys, G.W., & Braithwaite, J.J. (2011). Spreading suppression and the guidance of search by movement: Evidence from negative color carry-over effects. Psychonomic Bulletin & Review, 18, 690-696.

53.309 **Distractor heterogeneity effects in visual search are mediated by "segmentability"** Maria Yurevich[1](yurevichm@ya.ru), Igor Utochkin[1]; [1]National Research University 'Higher School of Economics'

Increased distractor heterogeneity complicates visual search, but only when the set of distractors has high dissimilarity (Duncan & Humphreys, 1989). However, if a gap between those dissimilar distractors in the feature space is filled with numerous intermediate feature values, it paradoxically improves the salience of a target singleton despite increased distractor heterogeneity (Yurevich & Utochkin, VSS, 2013). To explain this paradox we suggested that the distractor heterogeneity effect is mediated by "segmentability" – a threshold distance between neighbor features making them preattentively segmentable from each other or not. This predicts different heterogeneity effects on singleton search depending on the smoothness of transition between neighboring features: (1) search should improve when additional intermediate features provide smooth transition and (2) search should be impaired when those intermediate features provide sharp transition. We tested this prediction in our experiment. Observers searched for an orientation singleton (a 45° left or right tilted line) among 21, 31, or 41 lines tilted back from the target at various angles. Distractor sets could be homogeneous (either all vertical, or target-opposite tilted by 45°), heterogeneous distinct (vertical and opposite 45° tilts), heterogeneous sharp (vertical, opposite, and tilted by 22° between them), and heterogeneous smooth (containing eight transition angles, step was 5°). Both homogeneous conditions predictably provided the fastest search. The slowest and fastest among heterogeneous conditions searches were found in heterogeneous sharp and in heterogeneous smooth displays, respectively. The results support the concept of "segmentability" and its role as a mediator of singleton salience. Failing to separate distractors in the smooth condition into different subsets the visual system lumps them together in a quasi-homogeneous set and rejects them at once. Distinctly different distractors are separated and rejected successively yielding the slower detection rates. If heterogeneity is increased while closest features are still clearly distinct, search efficiency is yet lower.
Acknowledgement: The study was implemented within the Basic Research Program of the National Research University Higher School of Economics in 2013.

53.310 **Guiding search for camouflaged targets: Does color matter?** Alyssa Hess[1](alyssa.hess@knights.ucf.edu), Mark Neider[2]; [1]University of Central Florida, [2]University of Central Florida

Visual search in the real world often involves identifying a target that blends into its environment. Often, in such cases, a perfect target template is unavailable for guiding search. Previously, we characterized search for camouflaged targets in natural scenes with and without a target preview (Hess et al., 2013), and found little evidence for a preview benefit. Previ-

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ous research indicates that color is an important feature in guiding visual search. To determine whether this is the case in search for camouflaged targets, where targets are often poorly defined, we replicated our previous studies where participants searched for a camouflaged target in natural scenes, but in the current experiments search scenes were presented in grayscale. Manual response data indicated that, across four target sizes and experimental blocks, participants got faster to find the target with practice and with decreasing difficulty (manipulated via target size) in target present trials, regardless of whether or not they received a target preview (all $p < .05$), trends consistent with our previous findings in full color scenes. Accuracy data followed a similar pattern; however, no time-based improvements were found without preview. To characterize the influence of color information in guiding search, we compared the data from the current grayscale studies to those of our previous color studies. Regardless of whether a target preview was presented, there was no significant response time difference between color and grayscale scenes (all $p > .39$). However, when a target preview was provided, participants were more accurate in color compared to grayscale scenes ($p < .001$). Overall, our data suggest that during camouflage search, if color information regarding the target is provided observers utilize that information; in the absence of such information, however, target representations are based largely on alternative features, even as participants become more familiar with the target set.

53.311 Impetuous search execution is postponed for the purpose of an efficient conjunction search with a coherent target template

Junha Chang[1](junha.chang88@gmail.com), Joo-Seok Hyun[1]; [1]Department of Psychology, Chung-Ang University

Our previous study found that limiting the duration of exposure to target features ahead of a search could add a constant search delay, suggesting that search execution is held for a coherent target template (Chang & Hyun, VSS 2013). What was unclear was the purpose of waiting for the coherent template. To clarify this issue, we manipulated the exactness of target designation ahead of conjunction search while limiting the time for the template formation. These manipulations tested whether the search is executed impetuously by accommodating an inefficient search with an imperfect target template, or postponed until a coherent target template is ready for an efficient search. Experiment 1 used a conjunction search array of 4, 8, and 12 items consisting of colors and orientations, and Experiment 2 added shapes for triple-conjunction. In each trials, the pre-cue display, which was presented for 100ms in Experiment 1 and for 200ms in Experiment 2, had either an item looking 'exactly' like the target or a set of 'informative' items each sufficiently designating the target features, followed by a 50 or 700ms blank interval until the search array. The results showed that the RTs of the informative condition were relatively slower than the exact condition, and this delay was more evident in the 50ms condition, indicating that extra time was spent for the formation of a coherent target template in the informative condition. Nevertheless, the RTs for both pre-cue conditions were constantly delayed across the set sizes, regardless of the intervals, leaving no drops in search efficiency. The results suggest that, if the time for a coherent target template lacks, search execution is temporarily held for a set amount of time to prevent an impetuous execution of an inefficient search under an imperfect target template.

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53.312 Taming the White Bear: Learning Distractor Features Begins With a Cost, But Eventually Allows For More Efficient Search

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Some previous work suggests the surprising possibility that when subjects are given valid feature information (e.g., color) about non-target items, it actually hurts rather than helps their performance (e.g. Moher & Egeth, 2012; Tsal & Makovski, 2006). They suggest that this effect is due to a search process where observers first select the to-be-ignored item and then inhibit it, similar to the selection process of the "attentional white bear" effect. In Moher & Egeth (2012), observers were randomly cued with the color of the to-be-ignored item. Since observers were given a different color on each ignoring trial, learning a specific feature cue was not possible. However, is search still inefficient when observers learn that the target will never contain a constant specific feature (e.g. will never be red)? Using a similar paradigm to Moher & Egeth (2012), observers were prompted with either information about a non-target item in the search display (i.e. "ignore trials") or no information about the search display (i.e. "neutral trials"). Afterwards, they were asked to search a display for a capital letter "B" or "F" among other colored letters. Critically on ignore trials, observers were given one color (randomly assigned and counterbalanced across subjects) to learn to ignore for the duration of the experiment. Results revealed that early on in the experiment, there was a cost in reaction time (RT) on ignore trials compared to neutral trials, similar to Moher & Egeth (2012). However, after extended practice, RTs on ignore trials decreased significantly below RTs on neutral trials, suggesting that observers had learned to use more efficiently the information about the irrelevant feature. Overall, when observers learn to use information about non-target items, this process allows for more efficient search, just as when they learn to use information about target items (Sireteanu & Rettenbach, 2000).

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53.313 Serial Search Can Occur in Multiple Feature Dimensions at the Same Time

Steve Haroz[1](sharoz@northwestern.edu), William Prinzmetal[2], David Whitney[2]; [1]Psychology Department, Northwestern University, [2]Psychology Department, University of California, Berkeley

Some models of attention suggest that it acts as a single spotlight or actively selects only a single feature dimension at a time. However, we propose that inefficient attentional processes can operate simultaneously on multiple features. We ran five subjects in an experiment whose stimuli comprised an 8 x 8 grid of colored shapes. Each trial used 1 to 7 different colors and 1 to 7 different shapes. For half of the trials, a random cell was given a either a unique color or a unique shape. The task was to report whether an oddball was present or absent. The experiment included three blocks that asked subjects to report only an oddball color, only an oddball shape, or an oddball in either feature. For the color oddball task, increasing the number of colors resulted in slower response times (unsurprisingly), whereas the number of shapes had no significant effect on RT (surprisingly). We found the same results for the shape oddball task—adding more task-irrelevant, distracting colors did not affect RT. The implication is that search time is only serial as a function of the number of task-relevant feature variants (number of colors for color oddball / number of shapes for shape oddball). The multi-feature task, where the oddball could be in either feature dimension, produced a more surprising result. We again found no significant effect from the variant count of the non-oddball feature dimension. Only the variant count of the feature dimension with the oddball impacted performance even though subjects did not know which feature that would be. These results imply that two search tasks, which independently operate serially and inefficiently, are happening at the same time without a significant negative performance impact. Search in multiple features may operate as a race model which reports the first oddball detected in either feature.

53.314 Improving Search through Rapid Serial Visual Presentation

Chad Peltier[1](peltie11@gmail.com), Samuel Hemsteger[1], Mark Becker[1]; [1]Michigan State University

Previous research has found that participants can identify a target letter or number in a stream of rapidly presented items. More recently, researchers have shown that participants can detect a categorically defined target object in one of these rapid serial visual presentation (RSVP) streams. The results suggest that there may be practical applications for RSVP-based search. To explore this possibility, we performed two experiments that compared accuracy between a typical visual search task and a search in which the display was segmented and presented as a RSVP stream. Across conditions we equated the total search time. By presenting every segment of the overall display rapidly at fixation, the RSVP condition could benefit from the lack of attention shifts necessary in full display searches, a method that requires relatively slow eye movements and fixations. Experiment 1 presented 24 Landolt Cs (serially or in a whole display) and participants were required to identify the color of the C with a break on the left. Performance was significantly better for the RSVP condition than the full display condition. Experiment 2 replicated the RSVP advantage using much more complex scenes ("Where's Waldo?" images). These results suggest that real world searches may benefit from segmenting the display and presenting images in a RSVP stream.

53.315 Confirmation bias in visual search

Jason Rajsic[1](jason.rajsic@mail.utoronto.ca), Daryl Wilson[2], Jay Pratt[1]; [1]Department of Psychology, University of Toronto, [2]Department of Psychology, Queen's University

In this study we tested whether or not confirmation bias, a well-known decision-making bias consisting of a tendency to selectively search for and evaluate information expected to confirm a focal hypothesis, can occur in visual search. Participants completed visual searches for a target letter, and were asked to make one response when the target letter appeared in a specified color and another response when the target letter appeared in a different color. The set size was held constant at eight, and the critical manipulation was the proportion of the stimuli that were in the speci-

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fied color, referred to as the proportion of "hypothesis confirming" (HC) stimuli, compared to the unspecified color, referred to as the "hypothesis disconfirming" (HD) stimuli in a given search display. In Experiment 1, we found a confirmation bias, as participants searched through HC stimuli first, even when that required searching more items than searching through the smaller HD set. In Experiment 2, we attempted to attenuate the confirmation bias by incorporating a color preview display prior to the visual search display, so that participants could plan their search in advance of the stimuli appearing, therefore allowing them to implement an unbiased strategy. The results showed that the bias was attenuated, although participants were not able to detect the presence of a target letter in the HD set as efficiently as determining the absence of a target letter in that same set. Overall, these findings suggest that visual search is susceptible to confirmation bias and that this bias can be diminished by cognitive control mechanisms. Furthermore, this work shows that visual search can be used as a model for determining the role that attentional mechanisms may have in generating and maintaining confirmation biases.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada

53.316 **The effects of competitiveness on visual search** Carissa Romero[1](carissaromero7@live.com), Andrew Trevathan [1], Eriko Self[1]; [1]Department of Psychology, California State University, Fullerton

While many studies have examined the factors that influence visual search performance, how competiveness may affect a visual search task has not been investigated. Competiveness of the participants was measured using a subscale of the Competiveness Questionnaire, Interpersonal Competitiveness (IC). IC is a desire to win or do better than others. The goal of this study was to seek the potential relationship between IC and improvement in reaction time in a visual search task. The stimulus consisted of multiple red or green circles (3.5° in diameter) or squares (3.2° per side) that were presented on a computer screen. Each shape contained a white line segment (1.5° x 0.2°) in its center. The spatial configuration of the shapes was either circular (aligned on an imaginary circle of 14° radius) or random. The total number of shapes was 4, 8, or 16. The participant's task was to judge the orientation of the line segment (vertical or horizontal) in a target shape that is unique and different from all the others as soon as possible. Reaction time and response accuracy were recorded. Participants ran a first session of both spatial configurations, followed by the completion of the CQ. They were informed that their reaction time and response accuracy would be rank-ordered and compared among all the participants. Finally, the participants ran a second session of both configurations. The order of spatial configuration was counterbalanced across participants. They were categorized into two groups based on their IC score by a median split: the competitive group and the non-competitive group. The results indicated that the reduction in reaction time from the first to the second session was larger for the competitive group than the noncompetitive group for the circular configuration, but such a difference was not observed for the random configuration of the stimuli.

53.317 **Visual Search for MILSTD 2525 Glyphs** Navaneethan Siva[1](nxsivagnanasundaram@wichita.edu), Hannah Huffman[1], Alex Chaparro[1], Evan Palmer[1]; [1]Department of Psychology, Wichita State University

Glyphs are representations of multivariate data used for quickly discriminating information. They can represent values on more than one data dimension via physical attributes such as shape, size, and color (Ward, 2002). The United States military uses a set of glyph symbology (MILSTD 2525) to represent soldiers, equipment and personnel on the battlefield. In this study the authors selected a subset of features from these glyphs to i) evaluate their search efficiency, ii) determine whether differences in efficiency exist between levels of the same feature, and iii) identify the overall difficulty of search. The study compared 4 features: the length and orientation of a line, a central symbol and a text identifier. These represented air speed and direction, aircraft type and a unique aircraft identifier, respectively. Two variations of each feature were used to evaluate search efficiency across different levels of a given feature. Participants identified which side of the screen contained an oddball glyph, or if they saw no oddball. Set sizes 6, 12, and 18 were tested, with target absent trials occurring 10% of the time. Distractors were a set of homogenous glyphs from which the target stimuli only differed by a change in one of the tested features. Response time and accuracy were the major dependent variables, with search slopes being calculated for analysis. Results indicate that participants were not able to distinguish changes in text identifiers, with poor accuracy and relatively slow search efficiencies. Performance for most of the other features was excellent. Participants were slower at identifying a low level of air speed and directional change versus higher levels. This finding is consistent with other work in search asymmetries and indicates that interpretation of these glyphs may be more difficult for some situations than others.

53.318 **Right temporo-parietal junction involvement in visual feature binding** Stefan Pollmann[1,2](stefan.pollmann@ovgu.de), Wolf Zinke[1], Florian Baumgartner[1], Franziska Geringswald[1], Michael Hanke[1,2]; [1]University of Magdeburg, Department of Psychology II, Magdeburg, Germany, [2]Center for Brain and Behavioral Sciences, Magdeburg, Germany

We investigated the neural basis of conjoined processing of color and spatial frequency with functional magnetic resonance imaging (fMRI). A multivariate classification algorithm was trained to differentiate between either isolated color or spatial frequency differences, or between conjoint differences in both feature dimensions. All displays were presented in a singleton search task, avoiding confounds between conjunctive feature processing and search difficulty that arose in previous studies contrasting single feature and conjunction search tasks. Based on patient studies, we expected the right temporo-parietal junction (TPJ) to be involved in conjunctive feature processing. This hypothesis was confirmed in that only conjoined color and spatial frequency differences, but not isolated feature differences could be classified above chance level in this area. Furthermore, a race model inequality test applied to the accuracy values of the identified voxels within TPJ revealed that the accuracy of a classification of differences in both feature dimensions was superadditive compared to the classification accuracies of isolated color or spatial frequency differences. In addition, superior parietal representation of feature conjunction, reported previously by our group (Baumgartner et al., 2013) could be replicated. These data provide evidence for the processing of feature conjunctions, here color and spatial frequency in right TPJ, in addition to superior parietal cortex. References: Baumgartner, F., Hanke, M., Geringswald, F., Zinke, W., Speck, O. & Pollmann, S. (2013). Evidence for feature binding in the superior parietal lobule. Neuroimage, 68, 173-180.

Acknowledgement: DFG PO548/10-1

53.319 **Chemotherapy impairs visual search: A meta-analysis and a call to action** Todd Horowitz[1](todd.horowitz@nih.gov); [1]Basic Biobehavioral and Psychological Sciences Branch, National Cancer Institute, National Institutes of Health

Does chemotherapy impair selective attention? This is an important practical problem which demands input from basic vision science research. There is now substantial evidence that chemotherapy patients experience significant cognitive impairments. However, methodological problems make it difficult to determine which specific cognitive domains are impaired. The only point of consensus among the six existing meta-analytic reviews is that "attention" is not impaired. However, most neuropsychological "attention" measures have little or nothing to do with attention as vision scientists understand it; the majority are variations on memory span. Conversely, tests with some validity as attention tests (e.g., letter cancellation, Stroop) are sometimes excluded from the attention category. I re-analyzed data from one meta-analysis (Jim et al. Journal of Clinical Oncology, 2012), summarizing 17 studies of 807 breast cancer patients, tested at least 6 months after termination of chemotherapy. I extracted tests with some validity as selective attention tests (Stroop, test with a visual search component). I found a significant impairment for both Stroop (N studies = 5, effect size g = -0.214, p = .041) and search tests (N = 34, g = -0.080, p = .030). There was no search impairment in longitudinal comparisons (N = 9, g = -0.019, p = .074), or comparisons to healthy controls (N = 6, g = -0.043, p = .305); the effect was driven primarily by comparisons to cancer patients who did not receive chemotherapy (N = 19, g = -0.119, p = .020). However, in my view, none of these neuropsychological tests are properly designed to measure attentional function. There is a need for tests which are sensitive, designed to measure specific aspects of attention, and can be used to make direct connections to contemporary theories of attention and its neural underpinnings.

53.320 **Relationship between cerebral blood flow and body dissatisfaction in visual search task involving body-related information** Moe NAGAHATA[1], Masamitsu HARASAWA[2], Hiroshi ISHIKANE[1,3]; [1]Graduate School of the Humanities, Senshu University, [2]Science & Technology Research Laboratories, Japan Broadcasting Corporation, [3]Department of Psychology, Senshu University

It has been suggested that patients with eating disorders and healthy women with body shape dissatisfaction exhibit characteristic responses to information related to human body or food. Previously we indicated that participants with high body dissatisfaction detected human body-related stimuli faster than neutral stimuli in a visual search task. The present study investigated the relationship between body dissatisfaction and brain activity in healthy women using a visual search task involving body-related information. Participants comprised female undergraduate and graduate students without eating disorders. First, the body dissatisfaction subscale (part of the Eating Disorders Inventory) was administered to the participants. Subsequently, we performed an experiment using the visual search paradigm. Participants were shown stimuli comprising pictures of the human body and neutral stimuli not related to the body using a computer display. Either four pictures in the same category (target absent trial) or three pictures in the same category and one in a different category (target present trial) were presented simultaneously. In target present trials, the one is the target and the others are distractors. Participants judged whether the four stimuli were the same, or included one odd category by pressing a key. Their reaction times (RTs) and concentration of oxygenated hemoglobin (oxy-Hb) were recorded using functional near-infrared spectroscopy in the parietal and occipital regions. The RTs showed no dependence on body dissatisfaction. Moreover, in both the parietal and occipital regions, oxy-Hb negatively correlated with the body dissatisfaction score. The correlations occurred when the body stimuli were used as a target or distractors. These results suggest that the human body-related stimuli might be more salient; therefore, the stimuli might reduce the amount of resources necessary to perform the task for participants with a high body dissatisfaction score.

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Visual Search: Models and theories

Tuesday, May 20, 8:30 am - 12:30 pm

Poster Session, Jacaranda Hall

53.321 New exploration of classic search tasks

Honghua Chang[1,2,3](honghua.chang@gmail.com), Ruth Rosenholtz[2,3]; [1]School of Physics and Optoelectronic Engineering, Xidian University, China, [2]CSAIL, [3]Dept. of Brain & Cognitive Sciences, MIT

Traditional views of visual search have pointed to the importance of the presence or absence of certain basic “features” such as oriented or colored bars. Intuitions we have gained from running our recent model of search (Rosenholtz et al, 2012) suggest instead the primacy of concepts like tiling and coherence, as well as the less pithy insensitivity of a bag of derivatives to sign of contrast. Here we redesign five classic search experiments in ways that manipulate these latter factors while minimally changing the presence or absence of classic basic features: we take the bars making up classic search stimuli – Ts, Ls, Qs, etc. – and move them, or change their thickness, texture, or shape. We find search efficiencies of these slightly changed new tasks are significantly different from those of the classic ones, and not always in the way we expected. By only changing the thickness of the lines, we could make the O among Q task considerably easier (target-present search slope changed from 20.1ms/item to 13.1ms/item). In search for a T among Ls of two orientations, changing the horizontal bar in each symbol to a triangular “flag” made search less efficient (target-present search slope changed from 17.7 ms/item to 31.3 ms/item). We could make an easy Q among O task harder by simply moving the vertical line to a different part of the Q. Search efficiencies of classic and new conjunction tasks and tiled among vertical search tasks are also significantly different. These results highlight the importance of considering more image-based, less thing-based features in search, and the utility of model-driven stimulus manipulations.

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53.322 The role of lure heterogeneity in logarithmic visual search

Deborah Cronin[1](cronin2@illinois.edu), Alejandro Lleras[1], Simona Buetti[1]; [1]Department of Psychology, University of Illinois at Urbana-Champaign

During visual search, it is typically thought that possible targets (candidates) are selected from a search set, then serially inspected until the target is found (e.g., Wolfe, 1994). The relationship between search set-size and the amount of time it takes to locate the target is traditionally thought to be linear: the more items present, the longer it takes to complete search. Wolfe, et. al, (2011) demonstrated that this linear relationship does not translate to search in real scenes. Despite very large set-sizes, search in real scenes is highly efficient. Recently, Lleras, Cronin & Buetti (submitted) proposed a model for visual search (Information Theory of Vision, ITV) in which the RT X Set-Size function is mostly logarithmic. Instead of beginning with a selection of candidates, ITV proposes that search begins with the sequential rejection(s) of items unlikely to be targets (lures): lures dissimilar to the target are rejected rapidly and those that are more similar to the target are rejected more slowly. Because the search function is logarithmic, large set-sizes do not necessarily elicit extremely long reaction times, better modeling real-world search times. However, real-world scenes contain many different lures varying in dissimilarity to the target and thus in their ease of rejection. Here, we investigated the impact of an array having multiple types of lures on the RT X Set-Size function. Experiment 1 employed sets of two different lures highly dissimilar to the target. Experiment 2 employed sets of two different lures highly similar to the target. Trials in each experiment contained four candidate items and a varying number of lures from one or both sets. The results of these experiments provide supporting evidence for ITV and a better understanding of search in the presence of multiple non-candidate objects, as is the case in real world scenes.

53.323 A blurring based model of peripheral vision predicts visual search performances

Rachit Dubey[1](rach0012@e.ntu.edu.sg), Chun Siong Soon[1], Po-Jang (Brown) Hsieh[1]; [1]Neuroscience & Behavioral Disorders Program, Duke-NUS Graduate Medical School

The role of peripheral vision has been under-specified in most studies of visual search. Since attention is expensive, the peripheral visual field may provide information to help identify potential search targets. A recent work argued that information available in peripheral vision is a key determinant of search difficulty (Rosenholtz et al, 2012). Here, we build upon Rosenholtz’s patch-based discrimination strategy within the periphery, but instead of summary statistic computation, we consider how the larger receptive field sizes of peripheral neurons affect potential target identification. We suggest that larger receptive field sizes lead to a loss of spatial specificity, resulting in “blurring” of target and distracter items. Difficult search might arise when the blurred representations in the periphery are indistinguishable between target present and target absent patches. We first carried out seven different search tasks of varying difficulty in which participants had to find a target amongst an array of distracter items. For each search task, we then measured the discrimination performance on target present vs. target absent patch representations generated by our model. If a search condition is easy, then discriminating between a target present patch representation and target absent representation should also be easy, and vice versa. Results demonstrate a strong correlation between search performance and discriminability of patch representations generated by our model ($R2 = 0.94$, $p < 0.05$). Our results support the idea that visual search involves discriminability of peripheral patches, and is affected by the receptive field sizes of peripheral processing stream neurons, as proposed in our model.

53.324 Spatial deployment of attention in visual search: new evidence against a strict parallel model

Laura Dugué[1,2](laura.dugue@nyu.edu), Douglas McLelland[1,2], Mathilde Lajous[2], Rufin VanRullen[1,2]; [1]CNRS, UMR5549, centre de recherche Cerveau et Cognition, Faculté de Médecine de Purpan, 31 052 Toulouse, France. , [2]Université Paul Sabatier, 31 062 Toulouse, France.

Difficult search tasks are known to involve attentional resources, but the spatio-temporal behavior of attention remains unknown. Are multiple search targets processed in sequence or in parallel? We developed a new methodology (based on (Dubois, Hamker and VanRullen, 2009, J. Vis. 9(5):3, 1-11)) to solve this notoriously difficult problem. Subjects (n=14) performed a difficult search task (detect a T among L letters) during which two additional probe letters were flashed at varying delays, at randomly determined locations previously occupied by two of the search items. Performance in reporting probes at each location was considered as a measure of attention deployment. By solving a second-degree equation, we determined the probability of probe report at the most and least attended probe locations on each trial. Because these values were not equal, we conclude that attention was focused on one stimulus or sub-group of stimuli at a time, and not divided equally between all search items. Furthermore, this focalization of attention (measured as the difference between most- and least-attended probe report performances) was modulated periodically over time at a frequency of ~7Hz. These results definitively rule out a strict parallel model of attention processing during this difficult search task. Instead, they suggest that attention focuses on a subset of items, and periodically samples the search array.

53.325 Information pursuit as a model for efficient visual search

Hee Yeon Im[1](heeyeon.im@jhu.edu), Sheng-hua Zhong[1], Bruno Jedynak[2], Lisa Feigenson[1], Jonathan Flombaum[1]; [1]Department of Psychological and Brain Sciences, Johns Hopkins University, [2]Department of Applied Mathematics and Statistics, Johns Hopkins University

Theorizing about visual search has focused on whether search mechanisms operate over a single feature map (efficient) or over the conjunction of maps (inefficient). But why is it harder to search a conjunction of two maps than one map? We propose that information pursuit models can account for this difference at the algorithmic level. Information pursuit algorithms query successively smaller segments of space for the presence

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of a signal, but without estimating the signal's position within the relevant space. This contrasts with models that search narrowly and then passively accumulate signal to improve location estimates. Information pursuit models are optimal because they always acquire the maximum Shannon information possible within a limited search time; they also gain information at a constant rate throughout a search episode. Crucially, to operate efficiently, information pursuit requires a single input signal —in visual search, one feature map. We propose that efficient search relies on information pursuit, whereas inefficient search relies on alternative algorithms. In support, we report several efficient search experiments with limited exposures (starting at 17ms) after which observers clicked their best estimate of the target's position. We then characterized the microgenesis of an observer's knowledge of the target's position in terms of entropy (positional uncertainty), which declined at a constant rate and was fit better by an information pursuit model than a control model. Moreover, by modeling these exposure-limited trials, we accurately predicted reaction time distributions measured in a standard visual search procedure, as well as the shallow search slope typical of efficient search. Thus an information pursuit algorithm can explain the small amount of inefficiency that is characteristic of efficient search. Overall, our experiments, modeling, and mathematical derivations make explicit at the algorithmic level the kind of processing that can evolve rapidly with the inputs from a feature map.

53.326 **Logarithmic, sequential discounting of elements in a search display during feature search: evidence in favor of the Information Theory of Vision** Anna Madison[1](amadiso2@illinois.edu), Simona Buetti[1], Alejandro Lleras[1]; [1]Visual Cognition and Human Performance, Psychology, University of Illinois

Past theories of visual search for a feature singleton in a display dictate that visual search is highly efficient and RTs are basically unrelated to the number of elements in the display (Treisman & Gelade, 1980). Here, we show evidence that this view is fundamentally wrong. Lleras, Cronin and Buetti (submitted) proposed a new theory of visual search (Information Theory of Vision, ITV) whereby reaction times in a search task are proportional to the amount of information in the display. The uncertainty in a display is given by the number of possible target locations and the uncertainty about the identity of an item. The theory predicts that, initially, all items in a display will be processed and then, items most unlikely to be target (i.e., the ones carrying the most information) will be first discarded from consideration, reducing the location uncertainty of the target. Processing will continue on the remaining items, and so forth, until a final set of candidate targets is found and scrutinized in finer detail. Here, we tested the sequential discounting argument using a singleton search task (only one candidate in the display). Importantly, we included traditional visual pop-out conditions: the singleton (a red triangle) embedded in a uniform field of visual lures (elements that produce flat search slopes). The lures could be blue squares, yellow triangles or orange diamonds. In support of ITV, we found that RTs for uniform displays for all three different types of lures increased in logarithmic fashion. Further, we found clear evidence of sequential discounting by dissimilarity: using the slope estimates of the uniform displays, we were able to predict 94% of the variance of RT in heterogeneous trials, assuming discounting of most dissimilar elements first. These results clearly challenge current theories of so called "feature" search.

53.327 **Linear models of visual search are highly implausible: towards a better understanding of search in real world scenes using logarithmic search functions.** Zhiyuan Wang[1](gaykingwzy@gmail.com), Simona Buetti[1], Alejandro Lleras[1]; [1]Department of Psychology, University of Illinois at Urbana-Champaign

Lleras, Cronin & Buetti (submitted) proposed an Information Theory of Vision (ITV) that describes visual search as a combination of two sequential stages: attentional screening (driven by dissimilarity and logarithmic in nature) and attentional scrutiny (mediated by working memory and linear in nature). ITV is meant to capture both search in traditional experiments as well as search in real world scenes. A crucial prediction of this theory is that, based on information theory (Shannon, 1947) and Hick's law, the duration of the screening stage should be approximately logarithmic in terms of total setsize because processing time is proposed to be proportional to the amount of information in a display. Further, ITV proposes that only a subset of elements in the scene (candidates) produce a linear processing cost. An approximation of the reaction time formula (for large set sizes) is: RT=a+D*ln(setsize)+I*Nc Here, we compared the plausibility of ITV to that of theories of visual search that propose RT is a linear function of the number of items in the display (or a subset of them). We borrowed data from Wolfe et al. (2011) (data from Experiment 2), and performed a parameter estimation analysis comparing our model with traditional linear model: RT=a+I*Nc. In current theories of visual search, both inspection time I and the number of candidates Nc are thought to vary with each search scene, while in our model we fixed I based on data from Wolfe et al. (Experiment 3). Thus, both models have an equal number of undetermined parameters. We computed parameter pairs that gave minimum squared residuals with equal constant a and computed plausibility by finding the proportion of estimated parameters that fall within empirically observed ranges. Our results show that linear models of search are highly implausible whereas our model is highly plausible.

53.328 **Searching through the hierarchy: A behavioral and computational approach to understanding categorical search** Justin Maxfield[1](jmaxfieldsbu@gmail.com), Chen-Ping Yu[2], Gregory Zelinsky[1,2]; [1]Department of Psychology, Stony Brook University, [2]Department of Computer Science, Stony Brook University

How is the hierarchical structure of categories expressed in a categorical search task, and can we quantify the affects of this structure using a computational model of visual similarity? Trials consisted of a text cue designating a target category at either the superordinate, basic, or subordinate levels, followed by a 6-item target present/absent search array. Targets and distractors were images selected from ImageNet, and distractors on target-present trials differed from the target at the superordinate level. We found that search guidance, measured as the percentage of trials where the target was the first object fixated, was strongest at the subordinate level (29.9%), weaker at the basic level (25.4%), and weaker still at the superordinate level (20%), $F(2, 48) = 15.26$, $p < .001$. Target verification, measured as the time between target fixation and the present/absent search decision, showed the standard basic-level advantage; basic-level verification (978ms) was faster than subordinate (1173ms) or superordinate (1267ms) level verification. We modeled these data using dense-hierarchical-SIFT and pyramid-of-HOG features and Chi-squared statistics computed over hundreds of images per each subordinate/basic/superordinate category to obtain similarity estimates between each category and the specific exemplars used as targets in the behavioral search experiment. Analysis of these similarity distances revealed the behavioral guidance pattern; targets were most similar to the subordinate categories, followed by basic and then superordinate categories, $F(2, 286) = 58.09$, $p < .001$. This suggests that categorical guidance can be well described by Chi-squared similarity distance to a category. Moreover, a PCA analysis of the features revealed that the basic level required the fewest principal components, corresponding to the advantage seen during target verification. In conclusion, by adopting features from computer vision we show how a similarity-based exemplar model can be extended to real-world objects, and used to explain guidance and verification in categorical search.

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Perceptual learning: Methods and mechanisms

Tuesday, May 20, 8:30 am - 12:30 pm
Poster Session, Jacaranda Hall

53.329 **Learning of New Perceptual Groupings - A Biologically Plausible Recurrent Neural Network Model that Learns Contour Integration** Tobias Brosch[1](tobias.brosch@uni-ulm.de), Pieter Roelfsema[2], Heiko Neumann[1]; [1]Institute of Neural Information Processing, Ulm University, Ulm, Germany, [2]Netherlands Institute for Neuroscience, Amsterdam, The Netherlands

Problem. Mechanisms of perceptual organization can be subdivided into base-grouping, operating in parallel over the visual field, and incremental grouping that operates sequentially and requires selective attention (Roelfsema, Ann. Rev. Neurosci, 2006). The underlying neural mechanisms recruit circuits and cortical subsystems that interact in feedforward and feedback streams (Poort et al., Neuron, 2012). Evidence suggests that the neural computational mechanisms are not inert but are influenced by perceptual learning (Li et al., Neuron, 2008). It is currently unknown what the underlying mechanisms are to implement such perceptual learning. Method. We propose the biologically inspired REinforcement LEarning Algorithm for Recurrent Neural Networks (RELEARNN). Our model consists of mutually connected model areas that include intra-areal and inter-areal excitatory, inhibitory and modulating connections that influence the mean firing rates of model neurons. Learning alters these connections and utilizes a biologically plausible Hebbian plasticity mechanism that is gated by two factors, a localized attentional feedback and a global reinforcement learning signal. The model is shown to provide a biologically plausible link to the Almeida-Pineda backpropagation scheme (Almeida, IEEE 1987; Pineda, Physical Review Letters, 1987). Results and Conclusion. We demonstrate how RELEARNN can account for the performance of the visual system in two different grouping tasks. The first is a curve-tracing task, and we demonstrate that a model trained in this task qualitatively reproduces the activity profile of neurons in the visual cortex of monkeys. Activation of neurons that are driven by feedforward signals are enhanced by sustained laterally propagated modulations that serve as grouping label. The second task demands the detection of a “snake” of collinearly aligned contour elements. Here, the model reproduces psychometric performance curves as well as neuronal activity in monkey area V1. The new findings suggest that multi-stage grouping operations in the brain may be learned by one common learning mechanism.

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53.330 **Further evidence that connectivity differences may drive lateralization of visual processing** Ben Cipollini[1](bcipolli@ucsd.edu), Garrison Cottrell[2]; [1]Cognitive Science, UC San Diego, [2]Computer Science and Engineering, UC San Diego

Our neurocomputational model suggests that a difference in connectivity between cortical patches in the left and right hemispheres (LH and RH) can drive lateralization in visual processing (Hsiao et al., 2013). Anatomical measurements of BA 22 show an asymmetry in the average distance of long-range intrinsic axons that interconnect groups of selectively interconnected neurons (“patches”). Our model consists of two autoencoders (neural networks trained to reproduce their input on their output), where the hidden units represent the interaction between the patches. Similar to the neural system, our hidden units selectively interconnect nearby input units, have no asymmetry in the number of interconnections, but are asymmetric in the average distance between interconnected inputs. The model reproduces a number of behavioral asymmetries found in the visual processing literature. We extract hidden unit encodings for task-specific stimuli, classify the encodings according to the task, and compare performance across LH and RH networks. In addition, our model spontaneously shows predicted asymmetry in spatial frequency encoding. Here, we address a potential critique of the model. Previously, our autoencoders were trained only on the task-specific images used in the behavioral experiments. Here we train the models with natural images, then present them with the task stimuli, and they still reproduce the behavioral asymmetries modeled previously. We also made the model more biologically plausible by adding homeostatic scaling of synaptic weights and denoising properties; this further enhances spatial frequency differences. Finally, we show that the LH model in fact exhibits no spatial frequency preference--it is the RH model that shows a bias for low frequency information, at the expense of high. This is further evidence that our model’s behavioral asymmetry is driven by the anatomical structure of the model, and not due to other factors, such as an interaction between the training stimuli and the model architecture.

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53.331 **Feature distributions constrain visual object perception** Judith E. Fan[1](jefan@princeton.edu), Nicholas B. Turk-Browne[1]; [1]Department of Psychology, Princeton University

How does the visual system exploit statistical structure in the world to recognize objects? Here we examine how the distribution of features within objects alters perceptual discrimination of those objects. Object stimuli were plaid textures comprised of two overlapping sinusoidal gratings whose orientations varied independently over non-overlapping ranges (i.e., 1-89° from vertical in opposing directions). On each trial, two of these compound textures were presented and masked sequentially. Observers judged whether they were the same or different (defined by a ±15° rotation in one grating). Experiment 1 explored how the distribution of feature values affected discrimination performance. In an initial exposure phase, one grating (Uniform) was equally likely to appear in any orientation within its range, whereas the orientation of the other grating (Unimodal) was drawn from a truncated Gaussian distribution (peak=30° or 60°, across observers; s.d.=10°). In a subsequent test phase with the same task, both gratings were uniformly distributed, allowing us to test how learning of the distribution affected performance. Although now distributed identically, accuracy was impaired for the (previously) Unimodal vs. Uniform grating. These results are consistent with the possibility that this unimodal distribution promoted narrow tuning for that feature, resulting in impaired representations of objects containing atypical feature values. Experiment 2 examined how this impairment generalizes to more complex feature distributions. The orientation of one grating (Bimodal) was sampled from a mixture of two truncated Gaussians (peaks=30° and 60°); the other grating was Uniform. Again, we found that switching to fully uniform distributions at test impaired discrimination for the (previously) Bimodal vs. Uniform grating. This is consistent with tuning for multiple distinct modes, which resulted in less accurate object discrimination when features were drawn from a different distribution. Taken together, these findings illustrate how the distributional properties of features can have lasting effects on object recognition.

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53.332 **Augmented Hebbian Re-Weighting Accounts for Performance and Criterion Change in Perceptual Learning of Asymmetrical Vernier Stimuli** Jiajuan Liu[1](jiajuanl@gmail.com), Barbara Dosher[1], Zhong-lin Lu[2]; [1]Department of Cognitive Sciences, University of California, Irvine, [2]Department of Psychology, The Ohio State University

Previous studies showed that both block feedback and trial-by-trial feedback can facilitate perceptual learning (Herzog & Fahle, 1997). However, it is not clear how they facilitate learning similarly or differently. Using an asymmetrical set of vernier stimuli (-15’’, -10’’, -5’’, +10’’, +15’’) that contain more left than right offsets that has been shown to introduce response bias (Herzog & Fahle 1999; Herzog, Eward, Hermens & Fahle, 2006), Aberg and Herzog (2012) compared different forms of feedback and argued that both trial-by-trial feedback and block feedback support improvements in sensitivity, while only trial-by-trial feedback induces criterion shifts. Here we provide a comprehensive model for their complex results. Using the AHRM (augmented Hebbian Reweighting Model, Petrov, Dosher & Lu, 2005, 2006; Liu, Lu & Dosher 2010, 2012), we successfully modeled both overall performance change and behavioral shifts in response bias in the Aberg & Herzog (2012) data, including no feedback, trial-by-trial feedback with and without reversed feedback for -5’’, and similar forms of block feedback. The Hebbian learning algorithm incorporates trial-by-trial feedback, when present, simply as another input to the decision unit and uses observer’s internal response to update the weights otherwise. Block feedback alters the weights of the bias correction unit in the model (Liu, Dosher, & Lu, 2013). In the AHRM simulation, the response bias, or criterion shift, is induced by training on the asymmetrical set of vernier stimuli with trial-by-trial feedback, also influenced by reversed feedback. Training the asymmetric set incorporates biases into the weights between representation and decision. Block feedback counterbalances response bias with adaptive criterion control leading to less bias in block feedback conditions. The AHRM provides a detailed quantitative account for the results in Aberg & Herzog (2012), and makes generative predictions about differential training sets and feedback in perceptual learning.

53.333 **Visual perceptual training induces two dissociable learning effects** En Zhang[1](enenneuron@gmail.com), Wu Li[1,2]; [1]State Key Laboratory of Cognitive Neuroscience and Learning, Beijing Normal University, [2]IDG/McGovern Institute for Brain Research, Beijing Normal University

Our percept of a target stimulus can be affected by stimulus context. Previous studies on perceptual learning usually focus on improvement in discrimination of the target; it is unclear whether training can also modify the interactions between the task-relevant target and the task-irrelevant context. In this study we examined the effect of training on orientation discrimination in the presence of center-surround interactions. Human subjects were trained to discriminate an orientation difference between two successively displayed stimuli. One stimulus consisted of concentric grating patches, the inner gratings at a constant reference orientation, and the outer gratings at a different orientation to induce tilt illusion on the inner gratings. The other stimulus was similar to the inner gratings except for a small difference in orientation from the reference. This design allowed for a simultaneous measure of the threshold for orientation discrimination and the magnitude of the tilt illusion based on the psychometric curve. No error feedback was given. Our data showed that not only the threshold for orientation discrimination but also the magnitude of orientation illusion gradually decreased with training. The reduction of the illusion was maintained long after training, suggesting a long-term modification of contextual influences. Although training resulted in a parallel change in orientation discriminability and illusion magnitude, no day-by-day correlation of the learning effects was found. Moreover, by independently manipulating the orientations of the inner and outer gratings and keeping their containing angle identical, we found that the improvement in orientation discriminability was specific to the orientation of the inner but not outer gratings, while the reduction in orientation illusion showed an opposite effect. These results indicate that

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the training induced two dissociable perceptual changes, which could engage two different processes, a local process for enhancing orientation discriminability and a global process for modifying contextual influences.

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53.334 Investigating Neurochemical Involvement in Task-Irrelevant Perceptual Learning using Pupillometry Russell Cohen Hoffing[1](r-cohe003@ucr.edu), Aaron Seitz[1]; [1]University of California, Riverside

Little is known about how neurochemical systems are involved in human learning despite clear evidence that these systems are crucial to the plasticity underlying learning in animals. For example, norepinephrine (NE) is thought to act as a signal that "tells" the brain when to learn. Here we explore the hypothesis that NE is involved in a fast-Task Irrelevant Perceptual Learning paradigm using pupil dynamics as a surrogate measure of neurochemical activity. This hypothesis is motivated by evidence that pupil dynamics in monkeys are coupled with locus coeruleus activity (LC; the center of NE release). In this paradigm, participants conduct dual target and image recognition tasks each trial. In the target-recognition task, participants are presented with a stream of images temporally paired with an alphanumeric Target (e.g., a number) or Distractor (e.g., letters). Participants report the identity of the Target from a stream of Distractors and then report which of two images was in the image-stream. Each Target or Distractor paired image is presented for 133ms with an ISI of 1000ms, and pupil metrics are continuously recorded every 10ms. Participants showed increased recognition accuracy when the tested image was paired with a Target in comparison to tested images paired with Distractors. Pupil dynamics also indicated that pupil size changed more after Target processing compared to Distractor processing. Furthermore this effect was specific to subjects showing the improvement in memory processing for target-paired stimuli. A separate experiment utilized an unexpected sound to induce pupil size changes, confirming the relationship between pupil-size changes and memorization rates. Together, these results demonstrate a relationship between pupil size changes and task-irrelevant learning. While further research is required to demonstrate a casual link between NE activity and pupil dynamics, these results are consistent with the hypothesis that NE plays a role task-irrelevant perceptual learning.

Acknowledgement: NSF, NIH

53.335 Perceptual Learning With Indiscriminable Stimuli Lukasz Grzeczkowski[1](lukasz.grzeczkowski@epfl.ch), Elisa Tartaglia[2], Fred Mast[3], Michael Herzog[1]; [1]Laboratory of Psychophysics, Brain Mind Institute, Ecole Polytechnique Federale de Lausanne (EPFL), Switzerland, [2]Departments of Statistics and Neurobiology, University of Chicago, Chicago, IL, USA, [3]Department of Psychology, University of Bern, Switzerland

Perceptual learning is learning to perceive. For example, in a bisection task three parallel lines are presented. The central line is slightly offset towards the right or the left outer line. Observers indicate the offset direction. Training greatly improves performance. In models of perceptual learning, learning occurs by synaptic changes determined by the learning algorithm and the stimulus presentation. None of the models can learn when the very same stimulus is presented during training. Here we show that, surprisingly, humans can improve performance in such "impossible" conditions. We trained observers with a line bisection task where the central line was always exactly in the middle, i.e., the stimulus was the same in all 4160 trials. Participants were not told about the zero offset and were instructed to indicate the offset direction as in a normal bisection task. Surprisingly, performance improved with gains similar to "normal" bisection experiments where both the left and right offset are presented. These results cannot be explained by most of current models of perceptual learning and reproduce previous studies in the auditory domain (Amitay, Irwin & Moore 2006). We suggest that learning occurs by mental imagery in accordance with previous results (Tartaglia, Bamert, Mast & Herzog, 2009, 2012).

53.338 Dissociating Temporal Order & Simultaneity: A Perceptual Learning Study Nestor Matthews[1](matthewsn@denison.edu), Rebecca Achtman[1], Rachel Fenton[1], Brynn FitzGerald[1], Leslie Welch[2]; [1]Department of Psychology, Denison University, [2]Cognitive & Linguistic Science, Brown University

Introduction: Dynamic environments often contain stimuli that vary simultaneous and stimuli that vary sequentially. As a result, evolution would likely favor organisms that correctly judge simultaneity and temporal order. In principle, simultaneity judgments (SJs) and temporal order judgments (TOJs) could parsimoniously share a neural computation, i.e., the difference between the arrival times of two stimuli. To the extent that SJs and TOJs share this (or any) neural computation, one would expect practice-based improvements on SJs to generalize to TOJs. We tested this prediction by measuring TOJ accuracy before and after extensive SJ training. Method: Ten Denison University undergraduates viewed bilateral-stream RSVP displays containing two targets, one in each lateral hemifield, shown either simultaneously or at various asynchronies. Participants judged the targets' temporal order on the first and last days of our six-day procedure. Across the intervening four daily training sessions, participants judged whether the targets appeared simultaneously or not. Retinal stimulation remained identical across the SJ and TOJ tasks. Collectively, the participants completed 36,000 trials (600 trials per day * 6 days * 10 participants). Results: The percentage of correct simultaneity judgments (SJs) increased significantly between the first and second of the four SJ training sessions ($p<0.0005$), and remained asymptotically high thereafter. Despite this significant perceptual learning on SJs, TOJs before and after SJ training were statistically indistinguishable from each other ($p=0.568$, n.s.). Additionally, SJ accuracy significantly exceeded TOJ accuracy both before ($p<0.006$) and after ($p<0.01$) SJ training. Conclusion: Because significant perceptual learning on SJs did not generalize to TOJs, and SJ accuracy significantly exceeded TOJ accuracy, our findings argue against the parsimonious possibility that SJs and TOJs share a neural computation. Evolution appears to have missed a "two-for-one sale". Instead, our study suggests that the neural events mediating TOJs are separate from, and less accurate than, those mediating SJs.

53.339 The mechanisms underlying the fast and early improvement in PL Amit Yashar[1](amit.yashar@nyu.edu), Yang Hu[1], Jiageng Chen[1], Marisa Carrasco[1,2]; [1]Department of Psychology, New York University, USA, [2]Center for Neural Sciences, New York University, USA

Goal: Investigations of the time course of Perceptual Learning (PL) have postulated a fast-PL stage (within the first session) and a slow-PL stage (requires several sessions). However, the mechanistic differences between fast–PL and slow-PL are unclear. Recently, using an orientation visual-search task we found that slow–PL is specific to the trained dimension (orientation) but not to the irrelevant dimension (color), and that the specificity reverses for fast–PL. Here, to further explore and characterize fast-PL, we explored whether and how fast–PL relates to the binding of stimulus features by using a conjunction visual search. Method: Observers were trained to detect a target defined by an orientation X color conjunction among 25 line-elements. For example, they trained to detect a red line tilted 80° among 12 red lines tilted 50° and 12 green lines tilted 80°. After 720 training trials observers were tested with a target defined by a new combination of the features, in which the target swapped either its color, its orientation or both. Results: Training significantly improved observers' performance (d'). Learning transferred when target-feature swapped with a distractor its color or orientation; i.e., the performance remained at the level attained with training. However, there was no transfer when both target color and orientation swapped. Conclusions: These results suggest that fast-PL does not reflect an improvement in observers' ability to detect the specific features they were exposed to during training, but rather an improvement of their ability to bind the different features in the conjunction. This finding suggests that fast-PL is mediated by higher cortical areas, where features' representations are bound together, and that attention may play a role in fast-PL.

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53.340 Perceptual learning remains task specific with TPE training Jun-Yun Zhang[1](zhangjy1982@gmail.com), Lin-Juan Cong[1], Cong Yu[1]; [1]Department of Psychology, Peking University, Beijing, China

Visual perceptual learning is known to be specific to the trained retinal location, orientation/direction, and task. However, in previous studies we have used new "double training" and "training-plus-exposure" (TPE) training protocols to enable complete learning transfer to untrained locations and orientations/directions. Here we examined the task specificity issue by using a TPE protocol to test the hypothesis that perceptual learning may contain a task-independent component, and task specificity may result from an observer's unfamiliarity of the untrained task. Perceptual learning of contrast and orientation discrimination for a foveal Gabor and their mutual transfers were studied. The observers were trained with one task at threshold. Simultaneously in the same session in alternating blocks of trials or in later sessions they also performed and familiarized the other task at suprathreshold (4.5 x thresholds) (The exposure condition). Our results show: (1) Without the exposure condition both orientation and contrast discrimination learning was task specific, replicating known task specificity; (2) When the exposure condition was added, learning showed significant transfer to the other task, but the transfer could be accounted for by the effect of combined pretest and suprathreshold task practice, with no statistically significant evidence for extra benefits from the TPE (training plus exposure)

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protocol. These results suggest the boundary of our new training protocols in enabling the transfer of specific perceptual learning and support the known conclusion that perceptual learning is task specific, at least for our trained tasks, even with the TPE protocol. The results are consistent with our theory that during perceptual learning the observers learn the rules of performing a specific task. Such rules are applicable to untrained retinal locations and orientations/directions, but not to an untrained new task.

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53.341 **Different aspects of training on a texture discrimination task (TDT) improves different attentional abilities** Maro Machizawa[1](maro@brown.edu), Rebecca Patey[1], Dongho Kim[1], Takeo Watanabe[1]; [1]Department of Cognitive, Linguistic and Psychological Sciences, Brown University

It is well known that training of the texture discrimination task (TDT) leads to visual perceptual learning (VPL). Since VPL is specific for the location in which the trained feature was presented, it has been suggested that changes in the early visual cortex is involved in VPL of TDT. However, it remains unclear whether VPL is associated with improvement in higher cognitive functions including attention and whether the cognitive improvement is also specific to the location trained. In a meanwhile, it has been proposed that attention is classified into three different abilities: 'alerting', 'orienting' and 'executive control'. Since a stimulus used for TDT consists of foreground 'target' and background texture elements as well as a letter presented at the center of the stimulus for a fixation task, it is possible that different aspects of VPL are associated with improvements in different attentional abilities. Thus, we systematically manipulated experimental procedures to examine which attention ability is enhanced in association with a different aspect of VPL of TDT. Subjects were trained on TDT (Karni & Sagi, 1991) for 2 weeks. Before and after the training, we administered the lateralized attention network task (LANT; Green, et al., 2008) to effectively dissociate three attentional abilities. When subjects (n = 9) were trained on a conventional TDT with a stimulus consisting of both foreground and background textures, the 'executive control' was bilaterally enhanced. When subjects (n = 5) were trained on TDT with a modified stimulus with no background texture elements, subjects bilaterally improved attentional 'alerting'. These results indicate that VPL of TDT is associated with improvement in attention and that some different aspects of TDT training lead to enhancements in different attentional abilities.

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53.342 **The effect of directions of transfer in perceptual learning—a possible confounding factor in double training results** Qingleng Tan[1](qingleng_tan@brown.edu), Jeongmin Kim[1], Takeo Watanabe[1]; [1]Department of Cognitive, Linguistic & Psychological Sciences, Brown University

Visual perceptual learning (VPL) is defined as long-term improvement on a visual task as a result of visual experience (Sasaki et al., 2012). The improvement is usually highly specific to the location where the trained feature is presented, which refers to location specificity. Location specificity is regarded as manifestation of changes in early visual areas in association with VPL. Recently, Xiao et al. (2008) have demonstrated that location specificity of VPL is abolished by double training. For example, location-specific contrast discrimination learning can be rendered completely transferrable from the upper left to a new location in the lower-right quadrant if the new location is trained with an additional orientation discrimination task. This evidence challenges traditional views towards location specificity. However, the mechanism underlying double training remains unclear. In the current study, we applied a double training paradigm to investigate why it occurs. Subjects performed orientation discrimination training at the upper left quadrant for 6 days and then performed contrast discrimination training at the lower right quadrant for another 6 days. We found that, after the initial orientation discrimination training, the threshold significantly decreased at the trained location. In addition, the performance enhancement partially transferred to the lower right quadrant. However, hardly any transfer occurred at the upper right quadrant. The additional training led to some amount of improvement in orientation discrimination at the newly trained location, but not in the upper right quadrant. The result suggests that it is easier to trigger the transfer of orientation discrimination to the diagonal quadrant compared with the parallel quadrant. The effect of double training could be at least partially confounded by the fact that VPL is more likely to be transferred in diagonal direction than in parallel direction.

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53.343 **Alpha-band EEG activity as a signature of automaticity in perceptual learning** Brett Bays[1](bbays001@ucr.edu), Kristina Visscher[2], Christophe Le Dantec[1], Aaron Seitz[1]; [1]Department of Psychology, University of California, Riverside, [2]Department of Neurobiology, University of Alabama at Birmingham

In studies of perceptual learning, subjects are highly trained in specific tasks across many sessions in order to induce perceptual benefits towards the stimuli in those tasks. However, as subjects perform the same tasks across many training sessions, the task becomes automatized, especially in the presence of the trained stimuli. In this case, specificity of learning may be partly related to automatic processing of the trained stimulus sets. To investigate this hypothesis, we examined alpha-band activity, which modulates with attention directed to visual stimuli, as a measure of automaticity in an orientation discrimination task where participants were trained for 8 sessions to find an oriented target in a field of near-oriented distractors. Before and after this training, alpha-band activity was acquired via EEG as subjects performed the task with trained and untrained stimuli. Results show that alpha power increases overall following training consistent with less attention required to perform the task. Additionally, after training, alpha desynchronization was weaker on trials containing trained stimuli compared to untrained stimuli, even though performance was generally greater on trials with more alpha desynchronization. These data are consistent with the hypothesis that performance on the trained stimuli is more automatic and that less alpha desynchronization is required to achieve the same performance levels on trained compared to untrained stimuli. Furthermore they suggest that more effort may be expended on trials containing untrained stimuli. This has implications for perceptual learning, as transfer effects between trained and untrained stimuli may also depend on differential effort of the individual at the time of stimulus processing.

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53.344 **Linking predictive coding in visual cortex to object representations in the medial temporal lobe** Nicholas C. Hindy[1](nhindy@princeton.edu), Felicia Y. Ng[2], Nicholas B. Turk-Browne[1,2]; [1]Princeton Neuroscience Institute, Princeton University, [2]Department of Psychology, Princeton University

Actions change the appearance of objects in systematic ways, such as when opening a box or biting an apple. In a previous study, we showed that the medial temporal lobe (MTL) binds together different states of an object that are connected by such actions. In the current study, we use high-resolution fMRI to investigate how these object representations in the MTL may in turn license perceptual prediction when one object state is cued and a predictive action is executed. The study began with associative training in which cue stimuli appeared individually and subjects pressed a button to transform the cue into an outcome stimulus. For some cues ("strong coupling"), one outcome appeared when the left button was pressed and a different outcome appeared when the right button was pressed. For other cues ("weak coupling"), both outcomes appeared with equal probability irrespective of which button was pressed. Replicating our prior work, different action-outcome transitions for a given strong (but not weak) coupling cue were represented more similarly to one another in the MTL. To examine how this learning affected perception, we measured the extent to which outcomes were predictively instantiated in visual cortex when the corresponding cue-action transition occurred. To disentangle voxel activity patterns specific to cue-action transitions from patterns for the outcomes, we included trials in which each cue-action transition was followed by blank screen instead of an outcome, and trials in which each outcome appeared in isolation without a preceding cue and action. For strong (but not weak) coupling trials with a blank screen, voxel patterns in early visual cortex were more similar to the pattern elicited by the corresponding outcome than to patterns of unassociated but equally familiar outcomes. This suggests that object representations in the MTL may be a source of predictive coding in visual cortex.

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53.345 **Dynamic shifts in connectivity between frontal, occipital, hippocampal and striatal regions characterize statistical learning of spatial patterns** Elisabeth A. Karuza[1](ekaruza@bcs.rochester.edu), Lauren L. Emberson[1], Matthew E. Roser[2], Michael S. Gazzaniga[3], Daniel Cole[1], Richard N. Aslin[1], Jozsef Fiser[4]; [1]Department of Brain and Cognitive Sciences, University of Rochester (NY), [2]Department of Psychology, University of Plymouth (UK), [3]Department of Psychological and Brain Sciences, UC Santa Barbara, [4]Department of Cognitive Science, Central European University (Hungary)

Extensive behavioral evidence has revealed that humans automatically develop internal representations that are adapted to the temporal and spatial statistics of the environment. However, the neural systems underlying this statistical learning process are not fully understood. Recently, various neuroimaging methods have been employed to examine this topic, but these studies have focused exclusively on temporally ordered stimuli. Since spatial structure is a hallmark of object and scene perception in vision, the present functional magnetic resonance imaging (fMRI) study investigated the substrates and processes underlying complex spatial pattern learning. Neuroimaging data were obtained while 20 subjects passively viewed artificially created scenes with a pre-specified pair-based statistical structure. After three runs of exposure to 144 different 6-element scenes, subjects performed a yes/no task on base-pairs and cross-pairs. Using seed regions defined by relating magnitude of activation to this post-exposure behavioral learning performance, we examined changes in functional connectivity over the course of learning. In addition to a general increase in connectivity throughout exposure, we find a specific connectivity relationship between frontal, occipital, hippocampal and subcortical areas that was dynamically reconfigured as learning progressed. Specifically, we show that connectivity with frontal regions shifted from early visual areas to subcortical areas when comparing early and late phases of exposure. These results suggest that learning is not fully captured by a single, fixed "learning" network, but is reflected at least partially in dynamic shifts in connectivity across numerous cortical and subcortical areas.

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53.346 **Macular degeneration affects functional connectivity of primary visual cortex** Kristina Visscher[1], Rodolphe Nenert[2], Dawn DeCarlo[3], Richard Chen[1], Lesley Ross[4]; [1]Neurobiology, University of Alabama, Birmingham, [2]Neurology, University of Alabama, Birmingham, [3]Ophthalmology, University of Alabama, Birmingham, [4]Psychology, University of Alabama, Birmingham

Macular degeneration (MD) accounts for about half of all vision impairment or blind registrations in the developed world. It results in reduced central vision and impairment in tasks of daily living such as reading, driving and recognizing faces. In the human brain, the occipital lobe contains retinotopic representations of the visual field and the representation of the central retina in early visual areas is found at the occipital pole. Following loss of central vision, some studies have suggested that the portion of the primary visual cortex that would normally respond to central vision responds to attended peripheral visual stimuli. Some studies have suggested that this results from changes in top-down signals from regions that are higher in the cortical hierarchy. It is not known how connectivity between V1 and higher order areas changes following macular degeneration. Using BOLD fMRI, we measured changes in functional connectivity to primary visual cortex in a group of patients with central vision loss. We find that local functional connectivity between portions of V1 representing central vision and occipital regions representing peripheral vision are reduced in patients with MD relative to controls. Further, patients with MD showed relatively increased connectivity between V1 and the caudate. These results imply that one result of macular degeneration is a shift of connection patterns of V1.

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Binocular Vision: Summation, interaction and disparity

Tuesday, May 20, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

53.401 **Binocular asymmetry in amblyopia** Jian Ding[1](jian.ding@berkeley.edu), Dennis Levi[1]; [1]School of Optometry, University of California, Berkeley, CA 94720, USA

Humans with amblyopia have an asymmetry in binocular vision: neural signals from the amblyopic eye (AE) are suppressed in the cortex by the fellow eye (FE). In order to balance their binocular vision, the signal (contrast and/or luminance) from the FE must be reduced until the two eyes' contributions to binocular summation become equal (Ding, Klein & Levi, 2013b JOV, Ding & Levi, 2014 OPO, In Press). We define the binocular asymmetry to be the interocular contrast ratio AE/FE that results in balanced binocular vision. We used phase and contrast matching tasks to measure the perceived phase and contrast of a cyclopean sinewave, and fit the DSKL model, a binocular-combination model modified from Ding and Sperling (2006), to both the contrast and phase data. The binocular asymmetry was calculated from the best fit model. We found that binocular asymmetry in amblyopia depends on base contrast, mean luminance, and spatial frequency; the higher the stimulus contrast, luminance or spatial frequency, the higher binocular asymmetry. At a given spatial frequency, the binocular asymmetry can be described by a log-linear formula with two parameters, one for the maximum asymmetry and one for the rate at which the binocular system becomes asymmetric as contrast increases. We found that reducing the FE's luminance with a neutral density (ND) filter reduces its suppression of the AE, shifting the asymmetric line in parallel towards the symmetric line (AE/FE=1), thereby rebalancing the asymmetric binocular vision. However, because the binocular asymmetry varies with contrast, luminance, and spatial frequency, it is difficult or even impossible to rebalance the asymmetry for all visual conditions using a fixed ND filter. Nonetheless, wearing an ND filter before the FE (or increasing the luminance in the AE) may be more beneficial than the traditional method of patching the FE for treating amblyopia.

Acknowledgement: NEI: R01EY01728 and R01EY020976

53.402 **A novel method to quantify spatial-frequency dependent binocular imbalance in amblyopia** MiYoung Kwon[1], Emily Wiecek[1,2], Steven C. Dakin[2,3], Peter J. Bex[1]; [1]Department of Ophthalmology, Harvard Medical School, [2]UCL Institute of Ophthalmology, University College London, [3]NIHR Biomedical Research Centre at Moorfields Eye Hospital

Abnormal binocular experience during early development often puts the visual system at risk of developing amblyopia. Binocular imbalance of the amblyopic eye is a core deficit in amblyopia. While studies of contrast detection-threshold have suggested that amblyopic eyes show more pronounced deficits at high than low spatial-frequencies, supra-threshold apparent contrast may be unaffected at any spatial-frequency (Hess & Bradley, 1980). Recent evidence suggests that binocular imbalance may be visual-field dependent (Babu et al., 2013), but little is known about its spatial-frequency dependence. We therefore introduce a novel method to assess binocular imbalance rapidly with a dichoptic letter-identification task. Test stimuli were band-pass filtered Sloan letters with peak spatial-frequencies of 1 to 15 cycles per degree. The letters are arranged in a layout similar to the ETDRS acuity chart (4 rows of decreasing letter size by 5 columns of varying letter contrast) on a gray background. A different letter chart is presented to each eye of an observer via stereo-shutter glasses. At each position, the identity and interocular contrast-ratio of the letter on each chart differs while the spatial-frequency content of the letter remains the same. Subjects were instructed to read aloud the chart in top-to-bottom and left-to-right order. The relative contrast of the letter in each eye is adjusted across several charts to determine the critical contrast-ratio of the amblyopic eye: defined as the interocular contrast-ratio required to report the letter in each eye with equal probability. The critical contrast-ratio of amblyopic eyes was significantly greater for high than low spatial frequencies (from 0.75 to 0.95) while no significant spatial-frequency dependent changes were found in normally-sighted subjects (from 0.55 to 0.60). Binocular imbalance in amblyopia is therefore spatial-frequency dependent. The finding suggests that our novel quantitative method holds promise for characterizing spatial-frequency dependent binocular imbalance in amblyopic vision.

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53.403 A dichoptic action videogame improves the resolution of the amblyopic eye during binocular game play. Dennis Levi[1](dlevi@berkeley.edu), Indu Vedamurthy[2], Mor Nahum[1], Sam Huang[2], Jessica Bayliss[3], Daphne Bavelier[2]; [1]School of Optometry and Vision Science Graduate Group, University of California, Berkeley, [2]University of Rochester Department of Brain and Cognitive Sciences, [3]Rochester Institute of Technology, Computer Science Department

Playing action videogames with the amblyopic eye results in improved visual acuity, Vernier acuity, visual counting and in some anisometropic amblyopes, stereo acuity in adults with amblyopia (Li et al., 2011). To promote binocular fusion and stereopsis we developed a customized dichoptic action videogame game in which: i) the input to the two eyes is balanced by reducing the luminance of the non-amblyopic eye's image, and ii) the images to the two eyes are viewed in a mirror stereoscope, enabling fusion. To assess performance during game play we embedded a Gabor orientation discrimination task into the game. Importantly, the Gabor patch is only presented to the amblyopic eye, and its spatial frequency adapts to the resolution level of the player (the highest spatial frequency that the observer is able to discriminate), enabling us to monitor the amblyopic eye's resolution during binocular game play. Twenty-three adults with amblyopia played the game for 40 hours. All but one improved in visual acuity (by, on average, a factor of 1.4) and nine improved in stereopsis. The Interocular Luminance Ratio (ILR – the ratio of non-amblyopic eye to amblyopic eye luminance), a measure of suppression, showed a decrease in suppression by about a factor of 1.6, with a different time course in anisometropic and strabismic amblyopes. Importantly, the resolution of the amblyopic eye during binocular game play increased by a factor of 2.2, suggesting a reduction in suppression. Interestingly, the improved visual acuity and stereopsis were not significantly correlated with either the increased resolution, or decreased suppression in a binocular setting during game play. These results indicate that while reduced suppression or increased resolution may be necessary for improvements in stereopsis, they are not sufficient, calling for a more direct training of stereopsis in the next generation of video games for amblyopic patients.

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53.404 Monocular cuing does not modify interocular balance for dichoptic global motion perception. Lanya Tianhao Cai[1](tcai@sunyopt.edu), Ida Huang[2], Benjamin Backus[1]; [1]Graduate Center for Vision Research, State University of New York - College of Optometry, [2]Stuyvesant High School

The relative input strength of signals from the two eyes has recently been quantified in various ways (e.g., Hess et al., 2010; Ooi et al., 2013; Ding et al., 2013). Ooi et al. (2013) showed that an early stimulus to one eye increased that eye's weight during binocular combination, as revealed by changes in the interocular contrast balance to achieve equal effectiveness in binocular rivalry tasks. However, it is not clear how general this effect is within the hierarchy of visual perception. We asked whether early (300 or 50 ms) onset of contrast in one eye would reduce the contrast needed to detect motion direction in a dichoptic random-dot kinematogram (RDK), to determine the specificity of this enhancement. In a 2AFC motion discrimination task, coherently moving signal dots and randomly moving noise dots were displayed to the two eyes respectively. A 3-down 1-up staircase controlled the interocular signal-to-noise contrast ratio and measured the threshold at which the human observer reported the moving direction of the signal dots at 82% correct. A static monocular "cue" consisted of a group of high-contrast dots that was briefly displayed before the dichoptic RDK. The cue was displayed to the left or the right or neither eye when signal dots were in the left or the right eye; cue color was grey or else red to make the cue more salient. We tested both amblyopes and normally sighted observers. We found no systematic change in the interocular balance as a function of cuing. The cued eye showed no advantage in global motion perception. We suggest that (1) binocular processes in rivalry and RDK tasks do not inherit the same interocular balance, and/or (2) the early-cue effect requires that test stimuli not contain too much motion energy of their own.

53.405 Dynamic interocular suppression is uncorrelated with perception in early visual areas Katie L.H. Gray[1](k.gray@soton.ac.uk), Greta Vilidaitė[2], Rebecca E. Kitching[2], Kirstie H. Wailes-Newson[2], Daniel H. Baker[2]; [1]Psychology, University of Southampton, UK, [2]Department of Psychology, University of York, UK

Steady-state visual evoked potentials (SSVEPs) are contrast-dependent oscillations in the EEG signal induced by flickering visual stimuli. SSVEPs have been used to explore the mechanisms underlying binocular rivalry (Sutoyo & Srinivasan, 2009, Brain Res, 1251: 245-255), but to date they have not been used to compare activity between conscious and nonconscious vision during continuous flash suppression (CFS; Tsuchiya & Koch, Nat Neurosci, 8: 1096-1101). In CFS, high-contrast broadband masks are presented to one eye, causing stimuli in the other eye to be excluded from awareness. We investigated the effect of CFS on the SSVEP response to 1c/deg gratings (contrasts of 4-64%) or face stimuli. Targets were presented at 9Hz (sinusoidal on/off flicker) to one eye, with a Mondrian mask refreshing at 10Hz in the other eye, for trials of 11 seconds. We recorded EEG signals at 64 electrode sites, and Fourier transformed the waveforms to estimate the amplitude of the neural response at each stimulus frequency. The CFS mask reduced SSVEP responses to the targets (both gratings and faces) across the majority of the scalp. However, targets were not typically suppressed from awareness for the entire trial. When categorised by the subjective reports of the participant, no differences in SSVEP amplitude were found between conscious and nonconscious viewing at occipital electrodes. This implies a fixed level of interocular suppression in early visual areas. We also observed no amplitude modulation at more frontal electrodes, but this is likely due to insufficient activity at these sites owing to our necessarily small (~4 deg) target stimuli. We conclude that since CFS produces high levels of non-dynamic suppression in early visual areas, brain regions that correlate strongly with perception must lie further up the cortical hierarchy. Locating these with SSVEPs is challenging given the requirement to use small target stimuli to ensure complete suppression.

53.406 Binocular luminance contrast reduces dichoptic masking between chromatic stimuli Danni Wang[1](danni.wang2@mail.mcgill.ca), Frederick Kingdom[1]; [1]McGill Vision Research, Department of Ophthalmology, McGill University

Aim. Dichoptic masking refers to the increase in thresholds for detecting a target in one eye caused by a mask in the other eye. Here we examine the influence of binocular luminance contrast, i.e. luminance contrast that is presented equally to both eyes, on dichoptic masking between a chromatic target and a chromatic mask. Methods. Subjects were required to detect a violet disk on an isoluminant grey background in the presence or absence of a high contrast violet mask. Mask and test were either presented to both eyes (binocular condition), or to opposite eyes (dichoptic condition). All thresholds were measured with various amounts of added, binocular luminance contrast. Results. When both target and mask were presented to both eyes (binocular condition) the addition of luminance contrast had little effect on target detection thresholds in either the target-alone or target-plus-mask conditions. However when the mask was presented to one eye and the target to the other (dichoptic condition), target-plus-mask thresholds were systematically reduced by the addition of binocular luminance contrast in two out of three observers, even though the target-alone condition was little effected by luminance contrast. A control experiment showed that the reduction in chromatic masking from added luminance contrast only occurred when the luminance and chromatic contrasts were spatially contiguous. Conclusion: Binocular luminance contrast can significantly reduce chromatic dichoptic masking. The effect of the luminance contrast appears to be to reduce the interocular suppression between chromatic mask and target.

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53.407 Perceptual averaging of dichoptic mixtures of colour contrast promoted by task-irrelevant luminance contrast Lauren Libenson[1](lauren15@live.ca), Frederick Kingdom[1]; [1]McGill Vision Research, Department of Ophthalmology, McGill University

Aim: Previous studies have shown that under certain conditions the perceived contrast of a dichoptic mixture of two different luminance contrasts is similar to that of the larger of the two contrasts when presented binocularly, a scenario termed 'winner-take-all'. We ask whether dichoptic mixtures of different colour (chromatic) contrast obey winner-take-all, or instead obey the alternative scenario of 'averaging', in which the perceived contrast of the dichoptic mix is the average of the two contrasts. We also consider the effect of adding task-irrelevant luminance contrast to the dichoptic colour contrast mixtures. Methods:Subjects adjusted the contrast of a disk in one eye that was dichoptically superimposed on a test disk of fixed contrast in the other eye, until the perceived contrast of the mixture equalled that of a separate, fixed-in-contrast reference disk presented binocularly. Results:For isoluminant red, cyan, violet and lime disks the settings were close to winner-take-all. However, when a fixed amount of luminance contrast was added equally to all disks, i.e. was task-irrelevant, the settings shifted significantly towards averaging. Conclusion: The shift away from winner-take-all towards averaging caused by task-irrele-

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vant luminance contrast is consistent with reduced interocular suppression between the different dichoptic colour contrasts, and constitutes a new form of interaction between colour and luminance contrast in binocular vision.

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53.408 Dichoptic masking in color and luminance vision Yeon Jin Kim[1](yeon.jin.kim@mcgill.ca), Mina Gheiratmand[1], Kathy T. Mullen[1]; [1]McGill Vision Research, Department of Ophthalmology, McGill University

We have investigated the selectivity of contrast gain control for red-green color and luminance contrast thresholds using the method of cross orientation masking (XOM). Previously, for monocular and binocular stimuli, we have found that luminance contrast does not mask chromatic thresholds, suggesting selective, independent mechanisms of gain control for color and luminance pathways (Mullen et al., 12(9): 107, 2012). Here we explore dichoptic masking, and find very different results. Methods: First, we compare dichoptic XOM for three conditions: (1) chromatic test and mask (red-green isoluminant); (2) luminance test and mask; and (3) chromatic test and luminance mask (cross condition). Detection threshold vs contrast (TvC) masking functions were measured for horizontal Gabor targets overlaid with vertical Gabor masks for a range of spatio-temporal conditions (0.375, 0.75 & 1.5 cpd; at 2 & 8 Hz), with the test and mask presented dichoptically using a stereoscope. Second, we compare the timing for dichoptic and monocular XOM for chromatic and luminance stimuli by measuring the build-up of masking as a function of the duration of the target and mask. Results: Significant dichoptic masking is present with the same magnitude in all three conditions. In all conditions, dichoptic XOM is somewhat greater at low temporal frequencies (2Hz) than high (8Hz), and is independent of spatial frequency. Dichoptic masking builds up more slowly than monocular masking with no difference between chromatic and luminance contrast. Conclusion: The mechanism for dichoptic suppression is unselective, responding equally to both color and luminance contrast and their combination, with a similar time course for each. It is likely that there is a common color-luminance pathway for the dichoptic masking process, in comparison to the independent and selective pathways found for monocular and binocular conditions.

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53.409 A Novel Illusion Reveals Fundamental Differences in the Binocular Integration of Achromatic and Chromatic Information Jens Christiansen[1](jens.h.christiansen@gmail.com), Anthony D'Antona[2], Steven Shevell[3,4,5]; [1]Department of Psychology, University of Copenhagen, [2]Center for Perceptual Systems and Department of Psychology, University of Texas at Austin, [3]Department of Psychology, The University of Chicago, [4]Ophthalmology & Visual Science, The University of Chicago, [5]Institute for Mind & Biology, The University of Chicago

A new illusion demonstrates the difference between how achromatic and chromatic neural signals from the two eyes are combined binocularly. Two spatially homogeneous circles were presented separately to each eye at corresponding retinal locations. Each eye's circle alternated over time between the same two lights (either between 2 equiluminant or 2 achromatic lights). Temporal oscillation in the two eyes was always at the same frequency but opposite in phase. Square-wave frequencies ranged from 1.5 to 9.4 Hz. Equiluminant chromaticities oscillated around equal-energy-spectrum (EES) 'white' along one cardinal color direction (L/(L+M) or S/(L+M)) or along a diagonal direction that varied both cardinal directions simultaneously. Surprisingly, equiluminant modulation often resulted in very slow perceptual color alternation, with one or the other chromaticity remaining continuously visible for several seconds or longer. Oscillation along the achromatic axis, however, never resulted in slow perceptual alternation. Known neurophysiology of binocular integration of chromatic versus achromatic stimuli may explain the properties of the illusion. Peirce et al. (2008) recorded from binocular neurons in macaque V1 while presenting to each eye a spatially homogeneous field that alternated between two equiluminant chromaticities, or between two achromatic luminances. The color-tuning of the two monocular receptive fields of binocular neurons was well matched for neurons preferring chromatic stimulation but poorly matched for neurons preferring achromatic stimulation. In our illusion, stable periods of perceptual dominance of only one or the other chromaticity can occur because, when switching chromaticities between eyes, the response from binocular neurons preferring chromatic stimulation will be fairly stable. In contrast, binocular neurons preferring achromatic stimulation will have an unstable response and therefore cannot support a stable percept.

53.410 Binocular Mach Bands Kenneth Brecher[1](brecher@bu.edu); [1]Departments of Astronomy and Physics, Boston University

Mach bands are usually studied and treated as a primarily monocular phenomenon. That is, the standard underlying explanation – lateral inhibition arising from neighboring sensors in an individual eye – does not employ binocular vision to account for its main features. Nonetheless, even simple monocular experiments involving Mach bands are not fully accounted for by lateral inhibition alone (e.g., strength of the percept when varying the luminance gradient). As part of "Project LITE: Light Inquiry Through Experiments", we have developed a new Binocular Mach Band applet. This can be viewed on smart phones by free viewing. We have also developed a binocular viewer that - when combined with our software - can be used to probe a wide variety of binocular phenomena. The viewer and software have been designed to be compatible with many smart phones (iOS and Android based phones) and similar devices (e.g., iPods). The controllable software we have developed (found using a cell phone browser at http://lite.bu.edu) employs HTML5 that runs on several browsers on these devices. Together, the software and viewer help the observer experience a diverse range of binocular visual phenomena including: binocular rivalry; stereopsis utilizing new textured forms of random dot stereograms; binocular luster; as well as binocular addition of colors. Here we report results of our binocular Mach band experiments utilizing our viewing device and software. Novel Mach band phenomena that people report include both enhancement and total disappearance of the Mach bands with binocular viewing of oppositely oriented lightness gradients. The significance of these observations for the understanding of Mach bands will be discussed. Project LITE has been supported in part by NSF Grant # DUE-0715975.

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53.411 A novel 3D/dichoptic presentation system compatible with large field eye tracking Bo Cao[1,2](ffcloud.tsao@gmail.com), Arash Yazdanbakhsh[1,2]; [1]Center for Computational Neuroscience and Neural Technology, [2]Program in Cognitive and Neural Systems, Boston University

Traditional 3D and dichoptic presentation system usually uses a mirror stereoscope with a set of prisms and mirrors or colored glasses (red-green glasses) to split the view of the eyes looking at a computer display. Although these types of setups are useful in varieties of psychophysical and neuroscience studies, they have limitations. The colored glasses usually have a noticeable leak between the eyes. They also have a binocular rivalry effect over the visual field. Color glasses are hard to use for people with color deficits. Naïve subjects and clinical populations with visual impairment usually have a hard time to fuse with the mirror-prism setup. More importantly, the mirror stereoscope with a standard computer display usually does not provide a viewing angle that is big enough for a reliable measurement of fast and continuous eye movements over a large field. It is also insufficient for experiments examining visual motion and eye movements, for which it is crucial that the observers should not see the external reference frame, such as the edges of the mirrors. Although a projection system with a large screen and the active shutter glasses can provide a large viewing field, the active shutters can cause a 50% loss of the eye-tracking data. The presentation and eye-tracking system that we have developed can offer the following functions in one integrated setup: 1) No interruption of the eye tracking signals that currently occurs with active shutter glasses; 2) Large-field presentation, necessary for reliable measurement of the eye movement over a wide range of speeds and over a large distance; 3) Natural viewing experience like in movie theaters, which is important for reliable measurement in naive observers. The system is affordable and portable (except the screen), and can serve as part of other research setups, such as human brain imaging instruments.

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53.412 Ocular dominance and retinotopic correspondence enable patent stereopsis Cherlyn Ng[1](cherlyn.j.ng@gmail.com), Yaniv Morgenstern[1], Dale Purves[1,2,3]; [1]Neuroscience and Behavioral Disorders Program, Duke-NUS Graduate Medical School Singapore, 8 College Road, Singapore 169857, Singapore, [2]Department of Neurobiology, Research Drive, Duke University Medical center, Durham, NC, 27710, USA, [3]Center for Cognitive Neuroscience, B203 Levine Science Research Center, Duke University Box 90999, Durham, NC, 27708, USA

High resolution stereopsis in the Panum's fusional area (patent stereopsis) is often assumed to depend on matching corresponding image points. There is, however, no obvious way for the visual system to do this, a confound referred to as the "correspondence problem". The alternative

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we consider is that patent stereopsis depends on binocular information derived from monocular neurons with receptive fields that have the same retinotopic locus. To test this hypothesis, we evolved artificial neural networks stimulated by luminance that fell within the receptive fields of corresponding contralateral and ipsilateral monocular neurons. The responses triggered in this way were conveyed to an associated binocular cell tasked with reporting whether surfaces at its preferred eccentricity were nearer or further than surfaces impinging on nearby retinotopic loci, and by how much. Consistent with the results of visual physiology, we found that: a) far-tuned artificial binocular neurons evolved contralateral ocular dominance; b) near-tuned binocular neurons evolved ipsilateral dominance; and c) the degree of evolved dominance was not correlated with disparity tuning. These observations suggest that vision circumvents the correspondence and false target problems by means of retinotopy and ocular dominance, providing a plausible functional role for the latter.

53.413 Stereoscopic depth from absolute and relative disparities

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There has been a long-standing debate about the mechanisms underlying the human perception of stereoscopic relative depth. Relative depth between visual objects could be recovered in two different ways. The first one is using the difference of their absolute disparities, which are the differences of the monocular distances between each object and fixation point. A second more direct route consists of using relative disparities, i.e. differences in monocular distances between objects. Studies have claimed the existence of an independent relative disparity system from better performances in two-alternative forced choice discriminations between simultaneously presented stimuli compared to two-interval forced choice (2IFC) between successively presented stimuli, designed to isolate absolute disparities. However, memory noise and vergence noise can substantially reduce performance in the 2IFC task. Further, no previous study has controlled for visual references, leaving open the possible use of relative disparities in 2IFC tasks. We measured depth performance from absolute and relative horizontal disparities with a single stimulus method, involving a single memory component for both conditions. No fixation point was presented and the screen-border shape was in binocular rivalry. Participants were asked to judge the distance to the screen of two lines at the same depth (absolute condition) or the distance between two lines at different depths (relative condition). Vergence noise was also measured using nonius lines. If relative disparity is computed from absolute disparities, one can predict performance in the relative condition from performances in the absolute condition and from the vergence noise. Performance in the relative condition was significantly better than predicted performance, and better than absolute disparity performance. Interestingly, dress-makers displayed significantly better stereoscopic and vergence performance compared to a group of control participants. We conclude that either the relative disparity system is independent from the absolute disparity system, or that absolute disparities cannot be accessed directly.

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53.414 Cortical organization of binocular disparity in human V3A

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Our current knowledge of the columnar architecture of the cortex relies mainly on animal models, while much less is known about cortical organization in the human brain. The major barrier in understanding the fine-scale human brain computations comes from limitations in data acquisition. Standard fMRI resolution at 3T allows us to study large neural populations but not the microstructure. Here we use high-field (7T) functional magnetic resonance imaging (fMRI) to test for columnar organization for binocular disparity in human visual area V3A, an area previously associated with depth perception. We presented participants (N=5) with disparity-defined wedges ranging from fine to coarse disparity magnitudes (3 to 36 arcmin, crossed and uncrossed). During stimulus presentation, participants performed a demanding Vernier detection task at the central fixation point. We measured BOLD responses from dorsomedial visual cortex using 0.96x0.96x1 mm voxels and a 3D gradient echo sequence. We estimated disparity selectivity using general linear modeling, and then characterized the organization of voxel preferences across the cortical surface. First, we found that similar disparity preferences were clustered together to form structured maps that were reproducible across two different scan sessions. Then, we modeled individual voxel responses using Gabor-based filters inspired by electrophysiological recordings. We found that individual voxels were more frequently described as tuned to particular disparity values for fine disparities; however, when coarser disparities were tested, more voxels responded in a categorical (near vs. far) manner. These preferences for different types of voxel response (tuned vs. categorical) were clustered together on the cortical surface. Thus we provide evidence that human V3A is systematically organized to represent binocular disparity information, highlighting the importance of this area for stereopsis in the human brain.

53.415 Constancy of Perceived Depth from Disparity across Spatial Frequency

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Contrast constancy is observed in the luminance domain: gratings of different spatial frequencies have equal perceived contrast when they have the same physical contrast despite large differences in contrast thresholds. Seeing depth from disparity is quite different from seeing luminance variation. For example, depth from disparity is constrained by lower and upper bounds: lower-disparity thresholds and upper-disparity limits respectively. We investigated constancy in the disparity domain by comparing the perceived depth of disparity corrugations of different spatial frequencies. We presented a standard stimulus at 0.3cpd and a comparison stimulus at other frequencies. We varied the disparity amplitude of the comparison to determine the value yielding the same perceived depth as the standard. When the standard was near its lower-disparity threshold, more disparity was required in the comparison for equal perceived depth. When it was above its lower threshold, equal perceived depth occurred when the comparison had the same disparity; i.e., constancy was observed. When the disparity of the standard approached the upper-disparity limit, its perceived depth dropped precipitously. Equal perceived depth then occurred when the comparison's disparity was less than the standard's. Near the upper-limit the task could not be done with frequencies higher than the standard because these stimuli exceeded the disparity-gradient limit. Thus, depth constancy occurs across a broad range of corrugation frequencies provided that the disparity amplitude is not close to the lower-disparity threshold or upper-disparity limit. Low spatial frequencies avoid the disparity-gradient limit at all but the greatest amplitudes and can convey more apparent depth than other frequencies. Our findings call into question stereo compression algorithms that use lower-disparity thresholds to manipulate disparities in images and video and show that disparities near the upper-disparity limit warrant special consideration when creating stereo content.

53.416 Combining binocular disparities for depth volume perception

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Binocular disparity extraction is well understood for simple stimuli defining single objects or surfaces in depth. When scenes contain a complex pattern of elements, scattered at different depths through a volume, the disparity extraction process, and the combination of disparities for subsequent depth perception, is much less well understood. For example, it is not clear whether the disparity of each element is independently represented. Here we explored how disparity signals are combined to judge volume (or thickness) defined by binocular disparity. We tested two combination rules: (1) the difference between the means of crossed and uncrossed disparities; (2) the variance of the whole depth distribution. Stimuli consisted of lines elements with random orientation, x, and y positions. Elements were located on one of 4 depth planes. In the 'narrow' condition these were located at +/- 5.68 and 8.52 min arc disparity, in the 'wide', at +/- 9.94 and 4.26 min arc disparity. Mean crossed and uncrossed disparities were the same for these two conditions. Observers were asked to judge the thickness of the volume, compared to a standard stimulus where elements were distributed across a pair of planes in depth (14.2 min arc disparity apart). If rule (1) were used to combine depths for volume perception, we expected no differences between conditions. If rule (2) were used, we expected the 'wide' condition to be perceived as having a thicker depth volume. Or (3), observers might separately represent each plane and make judgements based on the outer planes only. Results were consistent with

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observers using rule 2. This suggests that the variance of the whole depth distribution is used to obtain an estimate of depth volume but that we do not have independent access to representations of the 4 separate planes.

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53.417 Effect of eccentricity on disparity distributions in binocular natural images

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Sparse statistical representations of natural images produce energy efficient components resembling the responses of simple cells in V1. These models assume that the statistics are spatially stationary, when in fact these statistics are known to vary across the image. We analysed the effect of eccentricity on the independent components of binocular images. A set of binocular image pairs were divided into three regions according to distance from the focal point. For each region separate FastICA models were trained using 100,000 patches 2x25x25 pixels in size. 4000 components per region were generated in batches of 200. Pairs of Gabor functions were fitted to each component. The binocularity of components decreased with increasing eccentricity. The differences in position, phase and orientation within each pair were used as measures of disparity tuning. This was only done for clearly binocular components. Confidence intervals were calculated using 200 bootstraps. The spread of the distribution of preferred horizontal position disparity was greater for samples from more eccentric image locations. In contrast, the spread of preferred vertical position disparity was not affected by eccentricity. The distribution of phase disparities was markedly less symmetric towards the centre of the image compared with eccentric regions. More components were tuned to large phase disparities in the centre of the image than elsewhere. Orientation disparities showed a small but significant decrease with eccentricity. From the geometry of binocular vision the observed distributions of horizontal and vertical disparities is to be expected. The asymmetrical distribution of preferred phase disparities was not predicted, since the role of phase in disparity detection is not yet fully understood.

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53.418 Temporal processing of first, second, and third order disparities by the human visual system

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The human visual system extracts disparity information from multiple sources, classified as first (luminance modulation), second (contrast modulation), and third (pattern/features) order. When these sources coexist, first order disparities are believed to play a dominant role. Here we present evidence to the contrary. We measured short-latency disparity vergence responses (DVRs) elicited in humans by the sudden presentation of binocular compound gratings, obtained by summing two or more sinusoidal gratings. Individual components were either all horizontal (with vertical disparity) or all vertical (with horizontal disparity). Appropriate combinations of spatial frequency (SF) and disparity yielded stimuli in which first, second, and third order signals coexisted, but had different SFs and disparities (of either sign). We found that with these stimuli the strength of the response to each signal is mostly determined by its own SF and contrast, just as when they are presented in isolation. Thus, the relative response strength to the three signals can be altered simply by scaling the stimulus. For example, in a 3F+5F stimulus first order dominates when the frequency of the fundamental F is low, and higher order dominates when it is high. At intermediate scales no one disparity signal dominates, and responses of similar magnitude to each type of disparity can be observed. However, because of the different latency of these responses (first order being the fastest, second order appearing 20ms later, and third order even later), they peak at different times. An exception to this rule is that at very low contrasts only first order disparities elicit DVRs. In conclusion, we found that in stimuli that contain multiple sources of disparity, DVRs simply reflect the relative strength of the various signals, determined by their individual SF and contrast. We found no evidence that first order signals play a privileged role.

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53.419 Vergence and Vertical disparity signals in Human area V1

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Last year we reported a dissociation between headcentric- and retinocentric disparity sensitivity in human cortical areas that respond to wide field (120 deg diameter) optic flow stimuli. Now we report a dissociation also between eye vergence response and horizontal retinal disparity processing in human area V1. We asked whether the vergence sensitivity in area V1 can be associated with non-visual and visual components. Exploiting the retinotopic organisation of area V1 voxels we show that the modulation strength of the BOLD signal by the horizontal eye vergence is dependent on eccentricity and meridional angle relative to the cyclopic eye, following a previously described relation between horizontal vergence and vertical disparity. This holds for eccentricities up to about 40 degrees,while beyond that eccentricity the modulation with eye vergence is not dependent on visual direction. This suggests that area V1 may carry signals for horizontal eye vergence both from non-visual sources and a visual source (vertical disparity) with partially non-overlapping representations. In contrast, no such dependency on visual direction was found for the modulation of the BOLD signal by horizontal stimulus disparity in area V1, ruling out a stimulus contrast effect of our wide field set-up.

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53.420 Attention to pattern depth depends on pattern dimensionality

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The perceived stereo depth separating two stimuli usually varies with the horizontal disparity difference between the stimuli. This, however, is not the case when one or both stimuli are one-dimensional. Instead, perceived depth depends on the difference between the disparity vectors of the two stimuli; relative disparity magnitude and direction both matter, interactively (Farell, Chai, Fernandez, Vis. Res., 2009). Here, we compare judgments of the depth of 1-D and 2-D stimuli, asking how attention affects this interaction. Our displays contained a central stimulus whose disparity varied across trials. This stimulus was either 1-D (a grating) or 2-D (a plaid). The stimuli surrounding the center were oblique-disparity plaids, the location of one being designated as relevant. The task was to judge the relative depth of the central stimulus and the relevant plaid; the remaining plaids were irrelevant throughout the block of trials and were to be ignored. Psychometric functions for depth judgments of the grating and the relevant plaid shifted laterally in response to the plaid's disparity direction (parallel or orthogonal to the grating's disparity). Interestingly, the disparities of irrelevant plaids produced exactly the same effect. Thus, attention failed to distinguish relevant and irrelevant stimuli when observers judged a grating-plaid pair. By contrast, when the stimuli being judged were both plaids, psychometric functions were affected neither by the disparities of irrelevant stimuli nor by the disparity direction of relevant stimuli. Attentional filtering of disparity signals thus succeeded only when observers judged the depths of 2-D stimuli. The judged depth of a 1-D stimulus varied with all the disparities in the display, whether relevant or irrelevant, revealing a disparity field that could be useful in transforming ambiguous 1-D component disparities into coherent object depths.

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53.421 Size matters: Perceived depth magnitude varies with stimulus height

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Stereoscopic acuity is known to vary with the overall size and width of the target. Recently, Tsirlin et al. (2012) suggested that perceived depth magnitude from stereopsis might also depend on the vertical extent of the stimulus. To test this hypothesis we compared perceived depth using small discs versus long bars with equivalent width and disparity. We used three estimation techniques. The first two, a virtual ruler and a touch-sensor (for haptic estimates), required that observers make quantitative judgements of depth differences between objects. The third method was a conventional disparity probe. This last technique, while often used for depth estimation, is a measure of disparity matching rather than quantitative depth perception. We found that depth estimates collected using the virtual ruler and the touch-sensor were significantly larger for the bar stimuli than for the disc stimuli. The disparity probe method yielded the same disparity esti-

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mates for both types of stimulus; which was not surprising given that they had the same relative disparity. In a second experiment, we measured perceived depth, using the virtual ruler, as a function of the height of a thin bar. In agreement with the first experiment, we found that perceived depth increased with increasing bar height. The dependence of perceived depth on the height of the stimulus is likely the result of the integration of disparity along the vertical edges, which enhances the reliability of depth estimation. The observed reduction in the magnitude of depth estimates for less reliable disparity signals may reflect a reweighting of depth cues or the expression of a bias towards small-disparities. Our results also underscore the often-overlooked difference between measurements of depth and disparity, as the effect of target height was obscured when the disparity probe was used.

Acknowledgement: NSERC

53.422 **When the Whole is Less than the Parts: Gestalt Grouping Degrades Depth Magnitude Percepts** Lesley Deas[1](ldeas@yorku.ca), Laurie M. Wilcox[1]; [1]Department of Psychology, Centre for Vision Research, York University, Toronto, Canada

The amount of depth perceived between a vertical line pair is markedly and consistently reduced when horizontal lines connect the pair to form a closed object (Deas et al, VSS, 2013). This phenomenon appears to be related to the operation of Gestalt grouping principles, however their role has not been evaluated systematically. Here we assess the contribution of specific grouping cues (connectedness, proximity and similarity) to modulations of perceived depth in simple line stimuli. In all experiments we presented four equally spaced vertical lines and manipulated the object interpretation of the central test pair. As in our previous work, the baseline comparison consisted of the set of four vertical lines (in isolation) contrasted with a 'closed object' version in which the central pair was connected by horizontal lines. In subsequent conditions we embedded the closed object in an array of equal-length horizontal lines (flankers), positioned above and below the horizontal connecting lines. We varied the colour of the connectors and flankers such that all lines matched or had opposite contrast polarity. In all conditions observers estimated the relative separation in depth of the central pair of vertical lines using a pressure-sensitive sensor. The amount of estimated depth was dependent on the perceived connectedness of the horizontal and vertical lines. Depth percepts were most disrupted when the horizontal connectors and vertical lines matched in colour. Perceived depth increased slightly when the connectors had opposite contrast polarity, but increased dramatically when flankers were added. Thus, as grouping cues were added to counter the interpretation of a closed object, the depth degradation effect was systematically eliminated. Our results confirm that depth perception for simple stimuli is dependent on figural grouping following Gestalt principles. Further, we propose that the modulation of depth from disparity is object specific, occurring within, rather than between, closed objects.

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53.423 **Subjective contour yielded by cue combination** Akiko Yasuoka[1](a.yasuoka@scu.ac.jp), Masahiro Ishii[1]; [1]School of Design, Sapporo City University

A random dot stereogram is a pair of images consisting of thousands of randomly placed dots with lateral displacements that produce depth perception when viewed stereoscopically. When an identical disparity is given to the dots within a region, one can perceive not only depth but a subjective contour on the boundary of the region. The subjective contour cannot be seen when the dot density of the stereogram is low. Imagine a chromatic defined region on a random dot image instead of a disparity defined region on a stereogram. For a dense random dot image, one can discriminate chromatic dots and perceive a subjective contour. The subjective contour cannot be seen when the image consists of sparse dots. In the current study, we investigate the effect of cue combination on yield of subjective contour. Three experiments were conducted as a series. Experiment 1 was conducted to determine the stimulus condition in which the subject can perceive depth of the dots but no subjective contour of the region from the stereogram. The stimulus consisted of white dots on a black background. The region was determined by a crossed disparity. Experiment 2 was conducted to determine the stimulus condition in which the subject can perceive the colored dots but no subjective contour from the image. The color of the dots in the region was green and the color of the dots out of the region was white. The dots in the region and the dots out of the region have zero relative disparity. The other experiment was conducted to investigate the effect of cue combination on yield of subjective contour. The stimulus conditions were determined using the results of the foregoing experiments. The dots in the region had both color and disparity. We found that the cue combination yielded subjective contour.

Acknowledgement: CREST, JST

Color and light: Neural mechanisms

Tuesday, May 20, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

53.424 **Rate Coding in Human Color Vision: The Curious Nearly Cubic Relationship Between Neural Spike Rates ans Psychophysical Color Sensitivities** Vincent Billock[1](billock.3@osu.edu); [1]College of Optometry, The Ohio State University

In sensory neuroscience, rate coding is the simplest and most common assumption; many psychophysical functions behave in a way that is roughly monotonic to the firing rates of some particular class of geniculate or cortical neuron.Somewhat less attention has been paid to the specific nature of the implied coding. An often cited example of rate coding in human color vision is that color naming seems to be predictable from power law transforms of specific geniculate neuron spike rates (De Valois et al., JOSA, 1966).More specifically, Young (JOSA, 1986) and Romney & D'Andrade (PNAS, 2005) assert that a cubic power law maps LGN firing rate inputs to cortex into psychophysical responses.I probed this curious assertion for luminosity and for chromatic valence. (1) Modeling psychophysical luminance sensitivity from the firing rate of broadband LGN cells. Depending on which datasets are matched, this yields power laws with exponents between 2.68 and 3.05. (2) Modeling chromatic valences from P-cell firing rates is trickier (because of mutual opponency between responding mechanisms) but is straightforward for wavelengths away from the valence crosspoints/unique hues. Preliminary calculations with the r-g psychophysical channel and various P-cell datasets indicate power law exponents in the range of 2.45-3.03. The nearly cubic relationship between some neural spike rates and some psychophysical behaviors is likely a consequence of many cortical neurons' Naka-Rushton expansive nonlinearities resembling cubic functions over a significant portion of their operating ranges. In contrast-transducing neurons the average Naka-Rushton exponent increases from 1.5 in LGN to 2.4 in V1 to 3.0 in mid-temporal cortex (Sclar et al., Vision Research, 1990). If wavelength-tuned neurons follow the same trend, a cubic function would be compatible with evidence of color-information processing along pathways that span V1 and temporal cortex (Conway, Visual Neuroscience, 2013).

53.425 **Color-detection thresholds in macaque monkeys and humans** Bevil Conway[1,2](bconway@wellesley.edu), Galina Gagin[1], Kaitlin Bohon[1], Adam Butensky[2], Monica Gates[1], Yiing Hu[1], Rosa Lafer-Sousa[1], Reitumetse Pulumo[1], Cleo Stoughton[1], Sonja Swanbeck[1], Jane Qu[1]; [1]Neuroscience Program, Wellesley College, Wellesley MA, 02481, [2]Department of Neurobiology, Harvard Medical School, Boston MA 02115

Macaque monkeys are a model of human color vision. The spectral sensitivity of the three cone classes in the two species is virtually identical, but monkey performance on psychophysical color tasks has not been well characterized. To address this gap in knowledge, we compared color-detection thresholds in three humans and three monkeys using colors sampled along eight directions in the equiluminant plane of cone-opponent color space. All subjects were tested on the identical apparatus with the same 4-alternative-forced-choice task. Targets were 2° square, centered 2° from fixation. Unlike previous comparative studies, performance was assessed after thousands of trials exhausting perceptual learning, using targets embedded in luminance noise (0.2° checks) to mask residual artifacts. At plateau performance, monkeys had lower color-detection thresholds than humans for colors that modulated L-M cones, but not for colors that only modulated S cones. Differences in the cone mosaics across species may account for these results. In particular, humans appear to have higher variability in the ratio of L:M cones, leading to large patches of a given cone type. Humans also have a small gap in S-cone distribution at the fovea, and a less regular S-cone distribution. These differences favor higher spatial acuity in humans compared to monkeys, which is consistent with previous evidence. Theoretically, we expect a tradeoff between spatial acuity and color acuity. Optimal spatial acuity would be achieved by an array of a single cone type (the output of a mixed array cannot be unambiguously assigned to luminance variation across an image). The present results suggest that selective pressures produced higher chromatic sensitivity at the cost of spatial acuity amongst monkeys compared to

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humans, specifically for the more recently evolved L-M chromatic mechanism. These selective pressures may also account for the dramatically lower rates of color blindness amongst monkeys compared to humans.

Acknowledgement: NSF (0918064), NIH (EY023322)

53.426 The Functional Asymmetry of ON and OFF Channels in the Lateral Geniculate Nucleus (LGN) during a Perceptual Decision Task

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At the level of the primate LGN it is well recognized that the parvocellular (P) and magnocellular (M) neurons constitute two parallel pathways that are physiologically distinguishable from each other. Each pathway can be further divided into those cells that preferably respond to contrast increments (ON-center), and those that preferably respond to contrast decrements (OFF-center). But what are the relative contributions of ON and OFF channels in a contrast detection task? Do OFF neurons represent contrast decrements the same way that ON neurons represent contrast increments? We recorded from LGN P ON and P OFF neurons in awake monkeys while they performed two-alternative, forced choice (2-AFC) contrast increment and decrement detection tasks, and found that: 1) OFF-center neurons were significantly more sensitive in contrast decrement detections (neurometric threshold = 47% contrast), compared with ON-center neurons in contrast increment detections (neurometric threshold = 67% contrast), 2) OFF-center neurons had consistently lower choice probabilities in contrast decrement detections (0.51) than ON-center neurons in contrast increment detections (0.54), 3) OFF-center neurons had, on average, lower Fano factors (0.9) than ON-center neurons (1.1), and 4) OFF-center neurons had shorter onset latencies (0.024 s) than ON-center neurons (0.04 s), but the neural sensitivities of both ON and OFF neurons peaked at around the same time (0.07 s) after stimulus onset. Thus there exists an interesting functional asymmetry between the ON and OFF channels in contrast detection: compared with ON neurons, the faster, more sensitive OFF neurons (i.e. with shorter latency, lower threshold, and lower Fano factor) were less correlated with the behavioral choice of the animal (i.e. with lower choice probability). Different possibilities, such as perceptual learning, adaptation, task strategy, cortical readout, distinctive temporal dynamics, and special interneuronal correlation structures, were subsequently explored, and comprehensive models were proposed to explain these results.

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53.427 fMRI adaptation of color and achromatic contrast in the human LGN and visual cortex: evidence for color and luminance selectivity

Dorita H. F. Chang[1](dorita.chang@mcgill.ca), Robert F. Hess[1], Benjamin Thompson[2], Kathy T. Mullen[1]; [1]McGill Vision Research, Department of Opthalmology, McGill University, Canada, [2]Department of Optometry and Vision Science, University of Auckland, New Zealand

Introduction: Color sensitive neurons in the primate visual system are thought to fall into two distinct types: a minority that are color selective with little response to achromatic contrast, and a majority that respond well to both color and achromatic contrast. The functional roles of these two populations are unknown. Here we use an fMRI adaptation paradigm to investigate the selectivity of the human LGN, V1 and extrastriate cortical areas to color and achromatic contrast. Methods: The effect of adaptation was measured in a block design comparing adaptation and no-adaptation conditions. Adapting stimuli were high contrast isoluminant RG or achromatic sinewave counter-phasing rings (0.5cpd, 2Hz, 12 sec duration) and test stimuli were lower contrast RG or achromatic rings presented for 18 sec. We assume that cross adaptation of responses to chromatic and achromatic stimuli indicates a common neural substrate for both, whereas a lack of cross adaptation indicates selective neural regions. Regions of interest (ROIs; LGN, V1, V2, V3, VP, V3A, V4, hMT+) were independently localized using standard procedures. Functional data were analyzed using percent signal change and fixed effects GLM analyses contrasting responses following adaptation versus no adaptation. Results: We observed the greatest adaptation effect when the adaptor and test stimuli were similar: after chromatic adaptation BOLD responses were lower for chromatic than achromatic stimuli, but after achromatic adaptation responses were lower for achromatic than chromatic stimuli. This effect was found in all ROIs and provides evidence for selective adaptation. Notably, we also found ROI-dependent variation in sensitivity to adaptation. In particular, hMT+ was most affected by adaptation to achromatic contrast for all test stimuli and exhibited the least selectivity. Conclusion: The results support the functional presence of color selective neurons in the human visual system that can adapt independently to color contrast, with the likely exception of hMT+.

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53.428 Temporal structure of Human Magnetic Evoked Fields to Colour, Form and Motion

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The temporal structure of responses to colour, form and motion stimuli are little studied. Here, we have extended VEP studies of colour and form response to magnetoencephalography (MEG). Seven participants (young adult) observed a projected dartboard comprising 9 patches with red/grey or blue/grey stimuli, presented either as diffuse surface colours or as a radial pattern. Each stimulus was presented at 5 levels of desaturation levels (100%, 75%, 50%, 25%, 0%) with constant luminance contrast (30%), using pseudo-random binary m-sequences (VPixx/DataPixx). Five minute recordings on the 306 sensor Elekta Triux MEG system were made using a 60 Hz frame rate. A motion/stationary pattern of white dots on black was used to extract motion onset fields. Wiener kernel analysis of the first-order K1 and the first two slices of the second-order kernel (K2.1, K2.2) revealed that the surface colour responses were largely found in the second order, while the pattern based colour responses were mainly found in first order. The surface colour K2.1 response showed strong saturation dependence for both red and blue desaturation series, while for exactly the same stimulus colours, pattern evoked K1 responses were hardly dependent on saturation (Blue Surface: Rsq=.23, p = .03; Blue Form: Rsq=.07, p=.26; Red Surface: Rsq=.23, p = .03; Red Form: Rsq=.14, p=.11). Motion onset evoked responses were characterized by peak field latencies of 95, 116 ms. Minimum norm source localization of the surface versus pattern evoked fields revealed peak activations in calcarine and lingual gyrus as well as early activation of the intra-parietal sulcus. The vastly different temporal structure, timing of peak fields and saturation dependence supports the notion that different neural populations subserve surface and form colour contributions.

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53.429 Parallel processing of colors and faces in human ventral visual stream: functional evidence and technical challenges

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Macaque monkeys possess a series of four color-biased regions arranged along the posterior-anterior axis of inferior temporal cortex, with each color region residing ventral and in close proximity to a face patch (Lafer-Sousa and Conway 2013). Moreover, face-selective patches appear to be more robust in the right hemisphere, and color-biased regions more robust in the left hemisphere. Color-biased regions and face patches are also found in humans (Bartels and Zeki 2000; Hadjikhani et al. 1998; Kanwisher 2010), but their spatial relationship to each other and their homology to those found in monkeys is unclear. To test the extent to which inferior temporal cortex is organized similarly in the two species, we sought to address three questions with fMRI experiments in humans: i) How far anteriorly do color-biased activations extend? ii) Do color-biased patches bear a systematic spatial relationship to face-selective patches? iii) Are color-biased regions left-lateralized? We scanned the same human subjects on contrasts designed to identify face-selective and color-biased cortex. Preliminary fMRI data from three subjects suggest that color-biased regions i) are found more anteriorly than previously reported in humans (N=2/3); ii) bear a systematic spatial relationship to face-selective regions; and iii) are somewhat left-lateralized. These results support prior indications of separate pathways for processing surface properties (texture and color) and geometric properties of objects in humans (Cavina-Pratesi et al. 2010). Definitively addressing the functional organization along the full anterior extent of the temporal lobe in humans will require overcoming the substantial susceptibility artifacts caused by the ear canals. Ongoing work is tackling these technical challenges, in an effort to determine the global organizational principles of the ventral visual pathway in humans, and the homologies between humans and macaque monkeys.

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53.430 **Brightness-Color Interactions in human early visual cortex**
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It is known that the interaction between brightness and color generates different color appearance for the same object. For example, an object is most colorful when its brightness is the same as the brightness of its surroundings. As the brightness difference between object and surround increases, the color appearance of the object weakens. However, it is not clear yet where in the cerebral cortex brightness-color interaction takes place. One possibility is that brightness and color signals are processed separately within V1 and only interact in higher visual cortex beyond the primary visual cortex (V1). Another possibility is that color and brightness contrast interact within V1. We localized the brightness-color interaction in V1 by means of recording the human chromatic visual evoked potential, the cVEP. We found that the cVEP was maximal when brightness contrast between color target and surround was zero. The behavior of cVEP from V1 decisively supports the idea that brightness-color interaction arises in a recurrent network in V1 in a winner-take-all manner. Furthermore, we also found that the color and brightness contrast at the edges between color target and surroundings are powerful determinants of perceived color as well as the cVEP. Recurrent inhibition in local cortical circuits has been called a canonical cortical computation and we show that this canonical computation implemented in V1 cortex has a strong influence on color perception.

53.431 **Diffusion Tensor Imaging Tractography Of Circadian Regulating Circuits In The Human Brain**
Kristin Koller[1](pspe60@bangor.ac.uk), Paul Mullins[1], Robert Rafal[1]; [1]School Of Psychology, Bangor University, Wales, UK

Circadian rhythms are endocrinological, physiological and behavioural rhythms that oscillate with a period close to 24 hours by precise orchestration of external environmental cues and internal neuro-endocrine circuits. By example, the rhythm of sleep is influenced by an external time-cue (light from the sun). Photosensitive melanopsin containing retinal ganglion cells transmit light signals through the inferior accessory optic tract to an internal pacemaker in the suprachiasmatic nucleus of the hypothalamus. The projection connects to sympathetic nerve fibres through the intermedio-lateral column of the spinal cord. From the spinal cord, sympathetic nerves innervate the pineal gland, via the superior cervical sympathetic ganglion, thereby stimulating secretion of the sleep inducing hormone melatonin. While the anatomy of this circuitry has been demonstrated by tracer studies in rats, a human anatomical homologue circuit remains to be established. Here we report results from virtual white matter dissections in nine humans, using probabilistic diffusion tensor imaging tractography. The dissection was achieved using a seed mask in the optic chiasm and waypoint masks in the periaqueductal region and the lateral medulla (through which projection from the hypothalamus to the sympathetics are known to traverse in humans.) The observed streamlines are consistent with the topography of circadian projections from the hypothalamus in the rat. Furthermore, the extent to which individuals reported to have 'early bird' sleep traits correlated with high mean fractional anisotropy (a measure of connectivity strength) of the streamline. Correlation findings reported here support the functional authenticity of our virtual dissections, and suggest that 'early bird' or 'night owl' chronotypes may be predisposed traits of hard-wired circuits in humans. Keywords: circadian rhythms, diffusion tensor imaging, hypothalamus, pineal gland, suprachiasmatic nucleus, sympathetics

53.432 **Melanopsin and cone specific temporal filtering revealed by non-linear pupil responses**
Long Luu[1](longluu@sas.upenn.edu), Manuel Spitschan[1], Geoffrey K. Aguirre[2], David H. Brainard[1]; [1]Department of Psychology, University of Pennsylvania, [2]Department of Neurology, University of Pennsylvania

The pupillary light reflex (PLR) is controlled by rods, cones (L, M and S) and intrinsically-photosensitive ganglion cells (melanopsin). The mechanics of pupil action result in minimal sensitivity to sinusoidal flicker above 5 Hz, limiting the usefulness of pupillometry for characterizing the temporal response properties of the visual system. Because of non-linearities in neural processing, however, we were able to use the PLR to amplitude-modulated flicker to measure the temporal transfer function of early photopigment-selective filters. Two observers viewed large-field (27.5°, central 5° blocked, 1125 cd/m2 mean light level) amplitude-modulated flicker with a pharmacologically dilated left eye while the consensual PLR was measured in the right eye. Using a spectral light synthesizer, flicker stimuli were generated to selectively modulate specific combinations of photopigments (L+M, S or melanopsin). We used amplitude-modulated stimuli at four carrier frequencies (5, 10, 20 and 40 Hz) and one envelope frequency (0.5 Hz). The carrier modulation contrast was 45% for all modulation directions; the envelope contrast was 100%. For each modulation direction and both subjects, we found a robust pupil response for 5-20 Hz carriers to a distortion product at the envelope frequency and at the envelope's first harmonic. This indicates that the 5 Hz cutoff in the conventional PLR occurs after a non-linearity. For both the S cones and melanopsin, the early filter revealed by the envelope-frequency response is low-pass and drops steadily to zero between 5 and 40 Hz. The similarity between S and melanopsin responses suggests that signals from these two photoreceptors share a common filter. The pattern for L+M was distinct, with a striking dip in response at 10 Hz—perceptually associated with a transition of stimulus appearance from chromatic to achromatic—and a robust response at 40 Hz.

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53.433 **Minimally distinct border estimates of macular pigment distribution**
John Erik Vanston[1](jvanston1206@gmail.com), Michael Crognale[1]; [1]Department of Psychology, University of Nevada, Reno

Introduction In cone-based color space, axes can be determined that selectively modulate different cone or cone-opponent systems. However, retinal inhomogeneities make it difficult to apply foveal-based determinations of these axes to large-field or peripheral stimuli. There are several methods for determining an individual or a local isoluminant plane that can partially solve this problem. What remains is the problem of locating specific axes (e.g. the S-cone isolating or tritan axis) within this plane as these are also affected by factors such as macular pigment distribution. There are various techniques for determining an individual's tritan line, including minimally distinct border and transient tritanopia that have traditionally been applied to foveal viewing. We present here a method for locally determining the tritan axis across the visual field using a modification of the minimally distinct border procedure. Methods Ten subjects (five female, mean age 26) with normal color vision viewed slowly rotating, circular, bipartite patches presented at five retinal eccentricities. These fields comprised two colors falling along an axis within an isoluminant plane in color space. Subjects rotated the color axes in color space until the border between the two chromaticities was minimally distinct. This was done for each of five retinal eccentricities, and repeated three times. Results Calculations of the location of the tritan axis with and without macular pigment accounted for most of the results from the minimally distinct border judgments. Interestingly, the magnitude of rotation required for a minimally distinct border was greater than predicted. Our modification of the minimally distinct border task seems to be a convenient and rapid method for determining an individual's tritan line (and consequently, macular pigment density) across the visual field.

53.434 **Noise masking of S+ and S- Tests: Linear Cone Combination Model Suggests Detection by Hue Mechanisms**
Rhea T. Eskew, Jr.[1], Timothy G. Shepard[1]; [1]Department of Psychology, Northeastern University

Psychophysical differences between the detection of S-cone increments and decrements (S+ and S-) were studied using bipolar, dynamic noise masks of several contrast power levels, with a forced-choice method. Noise chromaticities were L, M, and S cone, as well as L-M, L+M, and achromatic (L+M+S). We previously reported (Wang, Guilianini, & Eskew, 2002) that the threshold Energy vs. Noise (EvN) functions differed dramatically for S+ and S- tests. With identical noises, the EvN's for S+ tests are much steeper than those for S- tests (except for achromatic noise) even though the noises consisted of two symmetric chromatic polarities of equal contrast power. The S+/S- differences suggest possible contrast gain differences in S-ON and S-OFF pathways. Here we model the entire set of data (for each of two observers) by combining test energies across all noise chromaticities and powers, separately for S+ and S-. A model in which cone signals are linearly combined to produce mechanism noise power (Giulianini & Eskew, 2007) accounts for the S+ and S- thresholds surprisingly well ($r2 \geq 0.89$). The fitted relative cone contrast weights are nearly identical in three of the four cases (S+ and S- tests for both observers). In all four cases: (1) the L and M weights are of opposite sign; (2) the M-cone weight is largest in magnitude, larger than the S-cone weight; and (3) the S-cone weight is of the same sign as the L-cone weight. This pattern of relative weights is consistent with detection of these S+ and S- tests being mediated by a classical red-green hue mechanism, one with S cone inputs.

53.435 **Colour mixing and apparent motion: the effect of luminance contrast** Ben Jennings[1](ben.jennings@mcgill.ca), Frederick Kingdom[2]; [1]McGill Vision Research, Department of Ophthalmology, McGill University, [2]McGill Vision Research, Department of Ophthalmology, McGill University

Nishida et al. (2007) showed that when red and green bars alternate along an apparent motion trajectory, a single moving yellow bar is often perceived. They suggest this effect could be the visual system's attempt to integrate colors belonging to the same moving object. This conclusion predicts that other common bar features, e.g., luminance contrast, should contribute to the robustness of mixing, and that therefore less mixing should be observed if the stimulus is isoluminant relative to the background compared to if common luminance contrast is present. To test this we used a stimulus composed of spatiotemporally alternating red and green annular sectors that were presented circularly around the central fixation point. The stimulus was presented on a mid-grey background to enable isoluminant stimuli to be used. Perceived color mixing was measured using a single interval procedure, in which observers reported on each trial if the hues were perceived as mixed or as separate reds and greens. The independent variables were the angular subtense of the sectors, their presentation duration and the amount of added luminance contrast. Results indicated that the ranges of angular subtense and presentation duration over which perceived color mixing occurred decreased rather than increased with luminance contrast, by a factor of about 3.0 and 2.6 respectively. A control experiment measured discrimination thresholds for mixed versus non-mixed static red-green sectors, and revealed that the color mixing was not simply due to the chromatic system's reduced spatial acuity. These results contradict the object commonality hypothesis and points towards a lower level process in which luminance contrast suppresses spatiotemporal color blurring, which in turn facilitates the color mixing.

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53.436 **Rod influence on chromatic discrimination away from chromatic and achromatic backgrounds** Joris Vincent[1](jorisv@uw.edu), Steven Buck[1]; [1]Department of Psychology, University of Washington

Measurements of the sensitivity of chromatic discrimination are widely used in clinical assessments of color-vision deficiencies. Of both theoretical and diagnostic importance, the activity of rod photoreceptors has been shown to influence these discriminations, most often impairing discriminations mediated by L, M, or S cones. However, some studies show conflicting results, and offer limited understanding of the conditions that lead to specific rod influences on chromatic discrimination. Specifically, an unresolved issue is whether the rod influence is symmetrical between cone increment and decrement discrimination. The present study aims to investigate the conditions under which rods might influence chromatic discrimination by comparing discrimination threshold of 6 observers in bleached (minimal rod influence) and dark-adapted (maximal rod influence) conditions. Discrimination thresholds were set for L/M or S-cone isolating gratings, by incrementing or decrementing compared to a monochromatic or achromatic disk reference stimulus. Rod impairment of discrimination (consistent with previous literature) was found for most observers for extra-foveal stimuli, and for some observers for near-foveal stimuli. Moreover, the present study found mostly symmetrical rod influence on all axes of discrimination, as well as on all directions of discrimination. However, in the dark-adapted conditions at least 3 observers showed enhanced discrimination of extra-foveal chromatic stimuli on an achromatic background. These experiments show that the rod influence on chromatic discrimination is not consistent. Instead, different task procedure and stimulus – specifically discrimination away from achromatic – lead to variation in the influence of rods. The present study is in inconclusive on this apparent rod enhancement of chromatic discrimination: the same pattern of thresholds could result from impairment in the bleached condition. Further investigation of the rod effects on chromatic discrimination away from an achromatic background continues.

Color and light: Cognition

Tuesday, May 20, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

53.437 **Global color perception from multi-colored textures: Greater influences of saturated and frequent elements** Eiji Kimura[1](kimura@L.chiba-u.ac.jp); [1]Department of Psychology, Faculty of Letters, Chiba University

The present study investigated whether and how the visual system computes a single color (global color) as a statistical summary representation of the individual element colors in multi-colored textures. The texture pattern (2.5 × 2.5°, 30 cd/m2) consisted of equiluminant small squares of 3.3 arc min and their chromatic variation roughly belonged to the same color category. Element colors in the texture were selected from a circular color distribution on the CIE u'v' chromaticity diagram. The color at the center of the distribution was one of four colors (orange, green, blue, and purple) which were located at the distance of 0.05 units from a white point (CIE D65). For each center color, 8 satellite and 8 intermediate colors were determined at the distance of 0.02 and 0.01 units from the center color, respectively. The relative number of the center-color elements to the satellite- and intermediate-color elements was systematically manipulated in the texture. The observer matched the global color of the multi-colored texture by adjusting the chromaticity of a spatially-uniform matching stimulus. Results showed that when all element colors were equally frequent, the global color deviated from the colorimetric average toward the color of the highest saturation. But when the relative number of the center-color elements became larger, the global color became closer to the colorimetric average. Similar results were found even when the texture was composed of only satellite and intermediate colors and the intermediate-color elements were more frequent. The influence of the highest saturation was quantitatively different for different color categories, but this can be accounted for if differences in cone-opponent activities were taken into account. These findings are consistent with the interpretation that the global color is determined as a weighted average of cone-opponent activities in which more salient elements (saturated or frequent) are given greater weights.

53.438 **Color-motion feature misbinding without color** Natalie Stepien[1](nstepien8@gmail.com), Steven Shevell[1,2,3]; [1]Department of Psychology, University of Chicago, [2]Institute for Mind and Biology, University of Chicago, [3]Department of Ophthalmology & Visual Science, University of Chicago

PURPOSE. Previous experiments reveal that color-motion misbinding occurs in the periphery when central and peripheral objects share the same color, but move in opposite directions (Wu et al., 2004): The perceived illusory direction of peripheral objects is the same as the physical direction of central objects. This study tested whether color is necessary to elicit the illusory motion direction in the periphery, or whether shape-motion misbinding occurs without color. METHODS. The stimulus had moving objects in a central visual region and in adjacent peripheral regions. The objects were 0.3 deg long lines, half oriented vertically and half horizontally. In the central region, vertical lines moved in one vertical direction (say, upward) and horizontal lines in the opposite direction (downward). In peripheral regions, horizontal and vertical lines moved in the opposite directions (say, vertical lines moved downward, horizontal lines upward). All of the objects were either achromatic (metameric to EES 'white') or, in separate sessions, chromatic. In the chromatic condition, vertical lines were (say) red and horizontal lines green. In both conditions, observers fixated on a small cross in the center and judged the direction of motion of vertical lines in the periphery during a 20-second trial. The proportion of time with peripheral illusory motion in the chromatic condition was compared with the proportion in the achromatic condition. RESULTS & DISCUSSION. The proportion of time with illusory motion, and thus feature-binding errors, was greater in the achromatic condition than the chromatic condition ($p<0.01$ for each of three observers). Although introducing color increased the number of shared features between central and peripheral objects, feature misbinding was more likely without color. This shows that color is not necessary for motion misbinding, and that shape-motion misbinding in the periphery is at least as common as color-motion misbinding.

53.439 Color-motion feature binding errors are mediated by a higher-order chromatic representation

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PURPOSE: Recent work shows that chromatic similarity between central and peripheral moving objects regulates the frequency of color-motion binding errors in the periphery (Wang & Shevell, VSS 2012). This study tested whether chromatic similarity is determined by independent chromatic representations on the l=L/(L+M) and s=S/(L+M) cardinal axes, or instead by a higher-order chromatic representation. METHODS: The stimulus had moving objects in central and peripheral fields. In the central field, half the objects moved in one vertical direction and had one chromaticity, and the other half moved in the opposite direction and had a different chromaticity (e.g., red objects moved upward, green objects downward). In the periphery, moving objects had opposite directions (red downward, green upward). The chromaticity of green objects was constant (l=0.614, s=0.20) in both center and periphery, while the chromaticity of 'red' objects was varied in two conditions: (1) fixed in the periphery at (l=0.800, s=0.20), while in the center varied along the l axis (from 0.800 to 0.665, in separate runs) with s fixed at 0.20; (2) fixed in the periphery at (l=0.800, s=1.00), while in the center again varied in the same steps along the l axis with s fixed at 1.00. The proportion of viewing time with peripheral color-motion binding errors (red objects perceived to move opposite to their physical motion direction) was compared in these two conditions. RESULTS & CONCLUSIONS: The frequency of color-motion binding errors for a given l difference between center and periphery in condition 1 (with s fixed at 0.20) was different than in condition 2 (s at 1.00) ($p<.05$ for each of 3 observers), even though there was zero s-difference in both conditions. Therefore, color-motion feature binding does not depend solely on independent central-peripheral differences in l and in s. This implies color-motion binding depends on a more specific, higher-order chromatic representation.

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53.440 Color assimilation without awareness of color context

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Contextual effects are ubiquitous in color perception. For example, in color assimilation, the color of an object shifts towards the color of the inducing context. However, it is unknown whether this effect requires awareness of the inducing color context. We used our recently developed perceptual overloading technique (POT), which allows for extensive unconscious processing through repeated exposures, to test whether color assimilation occurs even when the inducing context is presented unconsciously. We presented two identically colored objects in two different color contexts, over several cycles, interleaved among colored masks. Although participants in the experiment were unaware of the inducing color contexts, they experienced color assimilation effects and reported perceiving the two identical disks as being different in color. These results demonstrate that color assimilation does not require awareness of the inducing color context and that the unconscious processing of these color contexts can have direct influences on the qualities of conscious color perception.

53.441 Expectations change the temporal discrimination of flashing stimuli

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The temporal sensitivity of human visual system was investigated. The two separate lights flashing at different temporal intervals were presented under neutral background. The three primary LED's (red, green and blue) were used as flash lights. The background extending full visual field was illuminated by D65 illuminant composed of three primary LED's. As each pair of stimuli flashed, subject reported "same", different", "left-first", or "right-first" to indicate whether the two lights appeared to flash at the same or at different times. We previously found that the temporal discrimination process has three stages (Stanikunas et al, 2012, Perception, 41 ECVP Supplement, 89). At the first stage stimuli are perceived as flashing together. At the second stage flashes are perceived as different in time, but it is not possible to tell which stimulus flashes first. At the third stage it is clearly visible which stimulus flashed first. Here we investigate how advanced knowing of stimulus flash order and expectations affect temporal sensitivity. Knowing. The threshold for temporal discrimination was measured by method of limits. Before each experiment subject either were instructed which stimulus will flash first, or didn't know flash order. Results show that knowing of stimulus flash order increases sensitivity for temporal discrimination and reduces decision errors. When the flash order is not known, perceptual errors are made during period of uncertainty. Expectation. Before each flash subjects were instructed to expect that stimuli will flash "left-first", "right-first" or will flash together. All stimulus timing presentation and three expectation instructions were presented in pseudo random order. We find that temporal discrimination threshold is affected by expectation. Lowest thresholds are when expectation coincides with flash presentation and biggest thresholds are when expecting opposite stimulus presentation.

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53.442 Lower in Contrast, Higher in Numerosity

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We report a new illusion in which there seem to be more grey disks than white disks when randomly-located white disks are intermingled with the same number of grey disks on a dark grey field. On a light grey field, there seem to be more dark grey than black disks. Of our 20 subjects, 19 experienced the illusion. Psychometric functions were obtained in a numerosity discrimination task to quantify the illusion with 30′ arc disks on a 10 deg-wide dark-grey field. Functions were reliably steep. The 50% point (which varied systematically with grey level) indicated that, in the best case, 32 grey disks matched 50 white disks in numerosity - an illusion of 36%. When the white and grey disks were not intermingled the illusion disappeared. We also tested shape: when the white and grey stimuli had different shapes (squares and disks with equal area), the illusion decreased to 8%. We conclude that similarly-shaped elements of different contrasts compete such that the higher-contrast elements are surprisingly under-estimated relative to the lower-contrast ones. Possible explanations include: (1) higher-contrast disks are seen in front, potentially occluding hypothetical lower-contrast disks that are unseen yet estimated; (2) the attended disks, typically those with higher contrast, group more and so seem less numerous; and (3) when contrasts are close, some higher-contrast disks are assimilated to the lower-contrast disks.

53.443 Task classification from eye movement patterns

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The early eye tracking studies of Yarbus (1965) provided descriptive evidence that an observer's task influenced patterns of eye movements, leading to the tantalizing prospect that an observer's intentions could be inferred from their saccade behaviour. If task influences eye movements in any systematic fashion, then it should be possible to determine the task of an observer using eye movement attributes alone. Recent attempts at such a classifier, however, have not been able to determine tasks above chance levels. Our approach is to train a classifier using eye movement data which has previously been shown to differ across task: Dodd et al. (2009) observed Inhibition of Return (IOR) in a search task but not in viewing, preference or memorization tasks. More than 17,000 saccades from 53 participants and 67 photographic images were used to train a Naive Bayes classifier on saccadic attributes such as latency, duration, peak velocity, amplitude and relative amplitude of sequential saccades. Ten-fold cross validation was used to maximize the data while preventing overtraining. The first classifier was trained with, and then used to classify based on, mean saccadic attributes for a given trial. The classifier was 45% accurate overall (chance is 25%), with highest accuracy for viewing (70%) and search (61%) followed by memorization (33%) and preference (25%). A second classifier was trained and tested using individual saccades. Even given just a single saccade, the algorithm was above chance at determining the task that produced it, with an overall accuracy of 31%. The classifier was more accurate for search (61%) and viewing (44%) tasks but there also was a bias in predicting these tasks resulting in below chance performance on preference (10%) and memorization (10%). We conclude that some tasks are discernible from patterns of saccades.

53.444 Cultural Analysis of Digital Display Preference

Jennifer F. Schumacher[1](jfschumacher@mmm.com), James M. Hillis[1], Robert W. Shannon[1], John F. Van Derlofske[1], Dave J. Lamb[1], Art A. Lathrop[1], James A. Thielen[1], Brian J. Stankiewicz[1]; [1]3M Company

It is known that there are some cultural differences in how humans process visual information [e.g., Saiki, et al., 2013]; however, little is known about cultural variation in preferences for display characteristics. While much of perceived display quality is likely based on the fundamental properties of the human visual system (e.g., visual acuity), other display properties, such as color and white point, may differ systematically across cultures.

Tuesday AM

Our study examined preferences for color gamut, white point, and gamma correction. Ten color gamuts, ranging from the standard sRGB area to over 130% NTSC (u'v' space) were simulated by symmetrically shifting all three primaries or just the red or green primaries. Four white points and two gamma values were also tested. The displays were calibrated and characterized at each location to control for variation in ambient lighting and changes in the displays over time. The experiment employed the method of paired comparisons where images of the same scene were presented on two displays positioned side-by-side. Each participant made 178 judgments per image for at least two images. Both real world and abstract images were used as image content. Experiments were conducted in multiple international locations across the globe, with at least twenty subjects from each locale, balanced for gender and including a wide range of ages. In general, people preferred displays with higher color gamut. Preferences for white point and gamma correction appear to be more susceptible to cultural influences. Interestingly, the variability in preferences differed, with more variability from Asian subjects. Image content also significantly impacted preference: preferences increased more systematically with real world images than abstract images. Previous work on image quality has also found a dependence on image content, which accounted for greater variability than the cultural differences [Fernandez, et al., 2005; Jun, et al., 2002].

53.445 A novel MDS methodology for studies of interactions between language and color Ryan Lange[1](lange.144s@email.osu.edu), Angela Brown[1], Delwin Lindsey[1,2]; [1]College of Optometry, The Ohio State University, [2]Department of Psychology, The Ohio State University - Mansfield

Recent studies from our lab show that language-related color categorization motifs vary both across and within cultures. Here, we adapted a multidimensional scaling (MDS) methodology from Shepard and Cooper (1978) to compare the relationships between color categorization and perception among English and Somali informants. Unlike English speakers, Somali informants often use the same word to name purple-violet and yellow hues. Our baseline protocol used 55 cards consisting of all pairwise combinations of 11 colors spanning the color circle. Eight optometry students ("ODS") rank-ordered the cards based on the color-pair similarity on each card. Rankings were transformed into color-sample Euclidean coordinates using nonmetric MDS, and mapped into CIELUV color space using Procrustes analysis. Subjects' chosen unique hues (blue, green, yellow, red) from a 40-sample Munsell color circle were also mapped into CIELUV. Next, we ran subjects (n=3 ODS, n=3 OSU undergrads, n=2 Somalis) on a 28-card subset of the cards from the baseline study (pairwise combinations of 8 colors). We obtained color difference rankings using a fast, forced-choice, binary sorting method. Aggregated MDS results from our 11-color baseline study showed a well-ordered, low-stress circular arrangement of colors in CIELUV that was close to the CIELUV loci of the stimuli. Unique hues were close to their independently-derived MDS counterparts. ODS and undergrads gave similar results using the 8-color protocol. Somalis' aggregate color space was generally similar to that of English-speaking subjects, with the notable exception that purple plotted near yellow. This exception agreed with Somali color naming behavior. In summary, we have developed a novel MDS methodology that reveals differences in color perception that correlate with differences in color naming behavior. Our methodology is fast (~ 20 min/subject), well suited for use in naïve subjects, and shows promise as a tool for investigating the relationship between linguistic color categorization and color perception.

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53.446 Hadza color naming and the origins of basic color categories Delwin Lindsey[1,2](lindsey.43@osu.edu), Angela Brown[2], David Brainard[3], Coren Apicella[3]; [1]Department of Psychology, Ohio State University, Mansfield, OH, [2]College of Optometry, Ohio State University, Columbus, OH, [3]Department of Psychology, University of Pennsylvania, PA

Most world languages have basic color terms, but how these terms emerge over time is unknown. To address this question, we report color-naming data collected in the field on the Hadza, a population of nomadic hunter-gatherers in Tanzania. Their language, Hadzane, is a language isolate and probably represents an early stage of color term evolution. Fifty-five color-normal (HRR plates) informants provided single name or "Don't Know" (DK) responses for each of 23 color samples, including focal examples of the 11 English basic lexical color categories (BCCs). All informants provided names for the red, black and white (RBW) samples, with only slight variation across individuals in the names chosen. The other 20 samples frequently elicited DK (32±11 DKs/sample; 11±4 DKs/informant). When informants did name non-RBW samples, consensus was low (9±2 terms/sample), even for the focal samples. Yet individual informants named colors lawfully; samples given the same name by an informant were usually adjacent in color space. Sets of samples named with the same term by individuals often resembled English BCCs. These sets were similar across individuals despite their designation with different terms. Our results provide insight into how color terms are acquired. Berlin & Kay (1969) hypothesized that all languages have basic color terms that completely partition color space. Contrary to this view, and in line with previous findings on color naming in another language isolate (Levinson, 2000), the shared lexical representation of color among Hadzane informants is remarkably sparse. That said, there appears to be emerging consensus in Hadzane about which samples should be grouped together by name and this consensus is consistent with the structure of the universal BCCs. More broadly, our data suggest that while not all colors necessarily belong to a BCC, when BCCs do emerge their locations in color space are subject to cross-culturally universal constraints.

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53.447 A Bayesian Approach to Grounding Color Vocabulary Brian McMahan[1](brian.mcmahan@rutgers.edu), Matthew Stone[1]; [1]Rutgers University

Perceptual properties in the world vary wildly. Despite this, linguistic decisions are consistently made to describe the perceptual properties, generalizing across many possible values and contexts. We propose a model of color and the ways people describe it. We used Randall Monroe's crowdsourced corpus of human color judgments to model grounded representations of color labels. Participants were presented with a uniformly sampled color patch and allowed to freely label it. After controlling for factors such as nonsense and spam labels, the corpus consists of 100,000 participants, 829 color labels, and 1.6 million color value and label pairs. In keeping with semantic accounts of color vagueness (Williamson, 1996; Barker, 2002), we treat color judgments as a function of its possible boundaries. In other words, there is a boundary that distinguishes subjectively true instances of a color label, but where that boundary lies in a context is uncertain. For example, it is uncertain where green ends and blue begins. However, once a blue-green color is labeled green, color values more green than it are definitely green. Further, we model the uncertainty in label meaning as a problem of Bayesian inference by treating the uncertainty as the combination of the prior expectation of a color label with how subjectively true the color label is of a color patch. Support is shown by comparing our model against two alternative models with different assumptions about the underlying color representation. The first alternative assumption is that labels maintain a Gaussian distribution over possible color values. The second is that labels are memorized in a histogram model of the color value space. We found our model to outperform the others. In conclusion, our model captures how people label color, and further, offers a way to ground representations of linguistic meaning in the perceptual domain.

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53.448 Emotional Mediation of Cross-Modal Associations in Timbre-Color Synesthesia William Griscom[1](wgriscom@berkeley.edu), Stephen Palmer[1]; [1]UC Berkeley

Previous research has shown that normal volunteers have an unexpectedly high level of consistency in their associations between individual colors and different musical sounds including intervals and instrumental timbres. These cross-modal associations seem to be mediated by emotional meaning, such that colors are consistently paired with sounds that have the same emotional valence (Griscom & Palmer, VSS 2013). In the present research, we extend this paradigm to look at the more unusual sound-to-color mappings that occur in individuals with audiovisual synesthesia. We recruited 15 volunteers who reported timbre-color synesthesia and verified their synesthesia using the Eagleman Synesthesia Battery (Eagleman, 2006). They then completed a series of tasks in which they reported their associated color experiences for a wide array of musical intervals and timbres, as well as for longer pieces of music, using a method similar to that used previously to measure associations in non-synesthetes. We found that these synesthetes have interval-color and timbre-color mappings which, although highly variable across individuals, on average show a structure similar to that of color associations reported by non-synesthetes in earlier studies. Both the synesthetic participants and a non-synesthetic control group showed strong effects of emotional mediation in their color pairings. In addition, we found that color-emotion synesthesia was most common type of synesthesia to co-occur with color-music synesthesia in our volunteers. Together, these findings suggest that audio-visual synesthesia is likely the result of a complex network of processes involving emotion and semantics, rather than simply being the result of an over-abundance of low-level connections in auditory and visual brain regions.

53.449 **Shape-to-Color Associations in Non-synesthetes: Evidence for Emotional Mediation** Michela Malfatti[1](malfatti.michela@gmail.com), Karen B. Schloss[2], Liliana Albertazzi[1, 3], Stephen E. Palmer[4]; [1]Center for Mind/Brain Sciences (CIMeC), University of Trento , [2]Department of Cognitive, Linguistic & Psychological Sciences (CLPS), Brown University, [3]Department of Humanities, University of Trento, [4]Psychology Department, University of California, Berkeley

There is growing evidence that cross-modal music-to-color associations are mediated by emotion in non-synesthetes (Palmer, Schloss, Xu, Prado-Leon, 2013; Whiteford, Schloss, Palmer, 2013). Here we investigated whether emotion might also mediate cross-dimensional shape-to-color associations in non-synesthetes (Albertazzi et al., 2012). Experiment 1 tested shape-to-color associations with 44 line stimuli that differed in the number of line segments (2/3/8), kind of edges (curved/angular), level of closure (open/semi-closed/intersecting-once/intersecting>1) and symmetry (asymmetric/symmetric). While viewing each stimulus, participants picked the three most consistent (and the three least consistent) among 37 colors. Later, they also rated each color and each line on 7 bipolar emotional dimensions (sad/happy, calm/agitated, not-angry/angry, passive/active, weak/strong, safe/harmful, and unpleasant/pleasant). The colors chosen to go with a line were well predicted by specific perceptual features of the line. In particular, more saturated colors were associated with more closed, angular, intersecting lines; darker colors were associated with more angular, intersecting lines; redder colors were associated with more angular, closed lines; and yellower colors were associated with more closed, angular, asymmetric lines. Consistent with the emotional mediation hypothesis, participants reliably associated colors with lines having similar emotional content for 6 of the 7 emotional dimensions, with correlations ranging from .84 for safe/harmful to .69 for unpleasant/pleasant. Preference (liked/disliked) also seemed to be related to color choices (r=.58). Principal Components Analysis of the dimensions showed that 91% of the variance could be explained by 2 components that roughly corresponded to not-angry/angry and sad/happy. Experiment 2 investigated similar shape-to-color associations for 45 closed geometric shapes that differed in the number of lines (3/4/9), kind of edges (curved/angular/pointy), concavity (0/1/>1 concavities), and symmetry (0/1/>1 symmetry axes). Results were similar in that the safe-harmful emotional dimension produced the highest shape-to-color correlations.

Motion perception: Biological

Tuesday, May 20, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

53.450 **Social interaction recognition: the whole is not greater than the sum of its parts** Stephan de la Rosa[1](stephan.delarosa@gmail.com), George Fuller[1], Heinrich Bülthoff[1,2]; [1]Max Planck Institute for Biological Cybernetics, Tübingen, Germany, [2]Koera University, Seoul, Korea

Physical interactions with other people (social interactions) are an integral part of human social life. Surprisingly, little is known about the visual processes underlying social interaction recognition. Many studies have examined visual processes underlying the recognition of individual actions and only a few examined the visual recognition of social interactions (Dittrich, 1993; de la Rosa et al. 2013, Neri et al. 2007; Manera et al. 2011a,b). An important question concerns to what degree the recognition of individual actions and social interactions share visual processes. We addressed this question in two experiments (15 participants each) using a visual adaptation paradigm in which participants saw an action (handshake or high 5) carried out by one individual (individual action) for a prolonged amount of time during the adaptation period. According to previous adaptation results, we expected that the subsequent perception of an ambiguous test stimulus (an action-morph between handshake and high 5) would be biased away from the adapting stimulus (action adaptation aftereffect (AAA)). Using these stimuli, participants were adapted to individual actions and tested on individual actions in experiment 1. In line with previous studies, we expected an adaptation effect in experiment 1. In experiment 2, participants were adapted to individual actions and tested on social interactions (two instead of one individual carrying out the actions of experiment 1). If social interaction recognition requires completely different or additional visual processes to the ones employed in the recognition of individual actions, we expected the AAA in experiment 2 to be absent or smaller than in experiment 1. In contrast, we found a significant AAA in both experiments (p<0.001) that did not differ across the two experiments (p=0.130). Social interaction and individual action recognition seem to be based on similar visual processes if paying attention to the interaction is not enforced.

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53.451 **Influence of eccentricity on action recognition** Laura Fademrecht[1](laura.fademrecht@tuebingen.mpg.de), Isabelle Bülthoff[1], Stephan de la Rosa[1]; [1]Max Planck Institute for Biological Cybernetics

The recognition of actions is critical for human social functioning and provides insight into both the active and the inner states (e.g. valence) of another person. Although actions often appear in the visual periphery little is known about action recognition beyond foveal vision. Related previous research showed that object recognition and object valence (i.e. positive or negative valence) judgments are relatively unaffected by presentations up to 13° visual angle (VA) (Calvo et al. 2010). This is somewhat surprising given that recognition performance of words and letters sharply decline in the visual periphery. Here participants recognized an action and evaluated its valence as a function of eccentricity. We used a large screen display that allowed presentation of stimuli over a visual field from -60 to +60° VA. A life-size stick figure avatar carried out one of six motion captured actions (3 positive actions: handshake, hugging, waving; 3 negative actions: slapping, punching and kicking). 15 participants assessed the valence of the action (positive or negative action) and another 15 participants identified the action (as fast and as accurately as possible). We found that reaction times increased with eccentricity to a similar degree for the valence and the recognition task. In contrast, accuracy performance declined significantly with eccentricity for both tasks but declined more sharply for the action recognition task. These declines were observed for eccentricities larger than 15° VA. Thus, we replicate the findings of Calvo et al. (2010) that recognition is little affected by extra-foveal presentations smaller than 15° VA. Yet, we additionally demonstrate that visual recognition performance of actions declined significantly at larger eccentricities. We conclude that large eccentricities are required to assess the effect of peripheral presentation on visual recognition.

53.452 **Neurodynamical model for the multi-stable perception of biological motion.** Leonid Fedorov[1](leonid.fedorov@cin.uni-tuebingen.de), Dominik Endres[1], Joris Vangeneugden[2,3], Martin Giese[1]; [1]CIN & HIH, Department of Cognitive Neurology, Univ. Clinic Tuebingen, Germany, [2]The Netherlands Institute for Neuroscience, Amsterdam, [3]University of Leuven, Belgium

The perception of biological motion integrates information over time and likely is dependent on the fusion of multiple cues. Under normal conditions biological motion stimuli result in unambiguous percepts. Recent work, however, has shown that certain biological motion stimuli can result in multi-stable perception and spontaneous perceptual switching (Vanrie et al. 2004; Jackson et al., 2010; Vangeneugden et al. 2012). An example is that specific views of walker stimuli induce alternating percepts of locomotion direction. METHODS: We extended a physiologically-inspired dynamical neural model for the processing of body motion (Giese & Poggio, 2003) by inclusion of a joint dynamic representation of the temporal order of intermediate patterns and stimulus view. This representation is modeled by a two dimensional dynamic neural field. Inclusion of noise results in perceptual switching between two different travelling peak solutions that correspond to the alternating percepts. The model was trained with walker stimuli in different directions and tested with ambiguous views. RESULTS AND CONCLUSION: The model is able to reproduce spontaneous perceptual switching between different perceived directions of biological motion, and at least qualitatively accounts for the dependence of this bistability on view angle differences. More detailed simulations reproducing psychophysical data on the multistability are in progress. REFERENCES. Giese M. A., Poggio T. (2003). Nature Reviews Neuroscience, 4, 179-192. Vanrie J. et. al. (2004). Perception 33: 547-560. Vangeneugden J. et. el. (2012). Society for Neuroscience Meeting, 127.04. Jackson J., Blake R.(2010). Journal of Neuroscience, 30, 838-848.

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 See page 3 for Abstract Numbering System

53.453 **The Influence of (Biological) Form on the Perception of Biological Motion** Maria Florendo[1](mflorendo28@gmail.com), Luke E. Miller[1], Jennifer Cook[2], Ayse P. Saygin[1]; [1]Department of Cognitive Science, University of California, San Diego, [2]Department of Psychology, City University London

In natural vision, the visual system must dynamically integrate form and motion. Here we explored the influence of an object's form on the perception of its motion. In a 2IFC paradigm, observers judged whether or not the motion of a target object was more natural in comparison to a reference object, a rectangle. The target motion had seven different levels of biological-ness, obtained by parametrically varying the amount of minimum jerk (MJ) and constant velocity (CV) in the trajectory. The rectangle always moved with 50% MJ and 50% CV. In Experiment 1, the target objects were a robot hand and a human hand. While these objects had similar shape, the former was noticeably metallic and artificial. Comparing the response curves revealed the robot hand needed significantly less biological motion (% MJ) than the human hand for its motion to be judged at the same level of biological-ness. We hypothesized that this effect might be driven by predictive influences; e.g., the robot hand might evoke prediction for clunky, mechanical movement, leading to its actual motion appearing more natural than it is. In Experiment 2, we included two more conditions: car (an inanimate object that moves) and house (an inanimate object that is typically stationary). Interestingly, responses for the car and house conditions did not differ from the human. For the robot hand, once again, significantly less biological motion was needed for naturalness judgments. Thus, while the form of an object can influence biological-ness judgments of its movements, there are constraints on this effect. We suggest that an object may need to be sufficiently similar to a biological object for biological motion prediction mechanisms to be able to influence its perception. Data thus far indicates similarity of shape (and not color or texture) might constrain interactions between form and biological motion processing.

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53.454 **Rehearsing Biological Motion in Working Memory: An fMRI Study** Zaifeng Gao[1](zaifengg@gmail.com), Xiqian Lu[1], Mowei Shen[1], Rende Shui[1], Shulin Chen[1]; [1]Department of psychology, Zhejiang University, Hangzhou, China

Holding biological motion (BM) - the movements of animate entities, in working memory (WM) is important to our daily social life. However, the neural mechanisms underlying the rehearsal of BM in WM remain unknown. The current study investigated this issue by hypothesizing that, analogous to BM perception, human mirror neuron system (MNS) is involved in rehearsing BM in WM. To examine the MNS hypothesis of BM rehearsal, we performed a human functional magnetic resonance imaging study by using point-light BM animations as the stimuli of interest. A matched non-biological object motion stimuli (moving circles) served as a further control. Previous perception studies have revealed that the perception of BM significantly activates posterior superior temporal sulcus (pSTS) and ventral premotor cortex (vPMC), both of which have been considered as core parts of human MNS system. In a change-detection task, we required the participants to remember 2 or 4 BM animations or circle motions. Sixteen valid participants took part in the experiment. In line with previous studies, we found that only the memorization of BM animations significantly activated the pSTS and vPMC. Moreover, higher memory load of BM led to significantly higher degree of activations in both brain areas. We concluded that the MNS underlies the rehearsal process of BM stimuli in WM.

Acknowledgement: National Natural Science Foundation of China (No. 31271089)

53.455 **Visual evoked potentials in response to biological and non-biological agents** Burcu A Urgen[1](burgen@cogsci.ucsd.edu), Wayne Khoe[1], Alvin Li[1], Ayse P Saygin[1]; [1]Department of Cognitive Science, University of California, San Diego

Although neuroimaging studies have advanced our understanding of cortical representations of object characteristics such as animacy, little is known about temporal aspects of associated processes. In the current study, we investigated with millisecond resolution when the brain shows differential processing of biological agents. We used unique stimuli consisting of images and videos of three agents: A female adult (human), a non-human agent that closely resembles her (android), and the latter in a more mechanical appearance (robot). The human agent had biological form and biological motion, the android had biological form and non-biological motion, and the robot had non-biological form and non-biological motion. Observers were shown the agents prior to the start of the study and told whether each agent was a human or a robot. We recorded EEG as observers viewed images and movies of these agents and analyzed visual event related potentials (ERPs). The amplitude of the P1 component (~80-120 ms) was significantly greater for the human, indicating the biological status of an object can modulate visual processing very early on. In fact, human-specific differences were observed even earlier than 80 ms, as part of the C1 component. Given the near-identical appearance of the human and android, it is rather implausible for these very early effects to be driven by stimulus properties. Instead, early human-specific responses are likely due to subjects' top-down knowledge of the agents' biological status, and the brain ascribing salience to the human agent from the very onset of the stimuli. The visual N1 (~150 ms) had greater amplitude for the robot condition, a modulation that is more likely to be driven by visual stimulus features. Overall, these data show that biological/non-biological status of an agent modulates visual processing very early on, likely due to ascription of salience to agents known to be biological.

Acknowledgement: DARPA, NSF, Hellman Foundation, Qualcomm Institute (Calit2)

53.456 **Functional Connectivity of Co-localized Brain Regions during Biological Motion, Face and Social Perception using Partial Correlation Analysis** Samhita Dasgupta[1](samhita@uci.edu), Sarah Tyler[1], Ramesh Srinivasan[1], Emily Grossman[1]; [1]Department of Cognitive Sciences, University of California, Irvine

Background: Perception and recognition of actions and intentions of others requires the successful coordination of brain systems supporting visual recognition, attention and cognitive control. Previous work has focused on the role of single brain regions in social cognitive tasks (e.g. the pSTS). Our current study aims to identify the functional connections within a shared large-scale cortical network, and how that pattern of connectivity supports the analysis of socially relevant information processing. Method: Subjects participated in three localizer tasks from socially relevant representative domains: 1) biological motion recognition: point-light biological motion versus motion-matched scrambled controls (Grossman and Blake 2001), 2) perceived animacy: social vignettes depicting geometric shapes engaged in social or mechanical actions (Martin and Weisberg, 2003), and 3) face perception: stationary faces versus pixel-scrambled faces (Hoffman and Haxby, 2000). We identified ROIs shared by the three tasks using a conjunction analysis across the localizers. We then subjected the timeseries from these regions to a partial correlation analyses that revealed unique functional connections between the ROIs. Results: Partial correlation analyses revealed large-scale patterns of unique connectivity across our conjunction ROIs, with hubs in the right hemisphere pSTS and inferior frontal gyrus (IFG). These hubs were uniquely connected to regions in premotor, lateral parietal and the posterior fusiform during all three tasks. Short-range functional connections emerged within lateral occipito-temporal cortex during the biological motion and perceived animacy tasks. Similarly, during the face perception and perceived animacy conditions, short-range connections emerged within prefrontal, parietal and ventral temporal connections. Conclusions: Our multivariate approach reveals the existence of a distributed network of brain regions with a core pattern of connectivity that is shared by biological motion, face perception and perceived animacy. We conclude this pattern of connectivity reflects the successful coordination of large-scale brain systems during social cognition.

Acknowledgement: NSF BCS0748314 to EG

53.457 **Using intersubject correlation of fMRI data to explore similarities and differences in action representation of Classical, Romantic and Modern ballet styles** Frank Pollick[1](frank@psy.gla.ac.uk), Naree Kim[2], Seon Hee Jang[2]; [1]School of Psychology, University of Glasgow, [2]Department of Dance, Sejong University

Theories of the neural systems involved in human movement processing do not clearly predict differences for the processing of different styles of movements. This can be seen in contrast to domains like dance where different styles of movement have developed for aesthetic and emotional effect. Taken together this would suggest the hypothesis that differences in the visual processing of dance styles would be minimal and that higher order cognitive areas would support differences in dance interpretation. To test this hypothesis we used fMRI to explore brain activity when novices viewed different styles of ballet. Visual stimuli were videos of 90-second long solo dances of Romantic ballet (Giselle), Classical ballet (Swan Lake) and Modern ballet (Agon). Stimuli were controlled by using the same dancer, costume, background, and starting posture. The order of the three videos was counterbalanced among 18 novice observers as they were scanned in a Siemens 3T Tim Trio scanner. Data were analysed with Brainvoyager QX and the Matlab-based Intersubject Correlation (ISC) Toolbox (Kauppi, et al., 2010). Preprocessing of the data included spatial

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smoothing with a Gaussian kernel of 6mm FWHM and coregistration of functional and anatomic data. Results of the ISC analysis provided a correlation map for each dance that showed largely overlapping regions in bilateral occipital cortex for all dances; no correlations were reported in frontal cortex. Statistical comparison of correlation maps of the three dances revealed differences. In particular, the Romantic dance revealed greater correlation in right somatosensory cortex and right inferior parietal lobe while the Classical dance revealed greater correlation in right lingual gyrus. These differences are consistent with ideas that form is critical for Classical ballet while emotion and kinesthesis are important for Romantic ballet. More importantly, results suggest a bottom-up role for basic mechanisms of movement processing to differentiate between dance styles.

53.458 **Measuring response saturation in human MT and MST as a function of motion density** Szonya Durant[1](szonya.durant@rhul.ac.uk), Michele Furlan[1]; [1]Department of Psychology, Royal Holloway, University of London

The response of neurons of human visual areas can be defined by two properties. The first is the functional selectivity, i.e. what is their preferred stimulus and what is not. The second is the rate of change of their response, i.e. how the response changes as a function of the preferred stimulus. Two of the best candidates to study these features are MT and MST. Although the functional selectivity of these two regions has been widely studied, the change in their response is still unclear. MT and MST response have been shown to increase linearly with motion coherence. In this work we measure the saturation function of these areas using a pure motion signal not embedded in noise. We used a 3T functional MRI to measure the hemodynamic activity in the human motion complex (MT, MST) and in primary visual cortex for comparison, while participants were exposed to different levels of motion density. We use spatially fixed apertures containing motion stimuli to manipulate the amount of area covered by motion, keeping local motion density constant and simultaneously stimulating over a wide area of the visual scene. We found that compared to the primary visual area, MT and MST responded above baseline to a very little amount of motion. We simulated population responses to our motion stimuli and found that the response function of the amount of motion versus static stimuli was well described by a simple model of divisive normalization. We then compared different types of motion and found no difference between coherent (uniform) and random motion at any motion density, suggesting that when combining response over several motion stimuli covering the visual field, a linear relationship of MT and MST population response as a function of motion coherence might not hold.

53.459 **rTMS to pSTS alters the ability to perceive walking direction of 3D point light walkers** Nicholas Adam Peatfield[1,2](nick.peatfield@gmail.com), Lorella Battelli[1,3]; [1]Center for Neuroscience and Cognitive Systems, CNCS@UniTn, Italian Institute of Technology, Corso Bettini 31, 38068 Rovereto Italy, [2]Center for Mind and Brain Sciences (CIMeC), University of Trento, Italy, [3]Berenson-Allen Center for Noninvasive Brain Stimulation, Department of Neurology, Beth Israel Deaconess Medical Center, Harvard Medical School

Our representation of biological motion allows us to decode its form and direction from impoverished stimulus such as point-light-walkers (PLWs). The dynamic nature of PLWs allows a variety of information to be gleamed from the stimuli, for example, gender, action, emotionality, of the PLW. So far though the majority of experiments have looked at PLWs without binocular disparity information. In the two experiments we assessed the ability to judge directional information of PLWs within a 3D display. In the first experiment participants made a delayed match-to-sample choice on the heading direction of a PLW, with two probe PLWs to choose from. For experiment two we conducted the same task but used repetitive 1Hz transcranial magnetic stimulation (TMS) to probe brain regions implicated within the task. 24 participants took part in experiment 1 where a QUEST procedure was used to measure the perception of angle in conjunction with 3D shutter-glasses to produce disparity information. 8 participants took part in experiment 2 and we tested two cortical sites in two separate conditions: left-hMT+, and left pSTS using the same task. PLW angle judgment was measured three times during each session: baseline before rTMS, post-rTMS and 30 minutes delayed-rTMS. Experiment one revealed an inversion effect for angle sensitivity, with an increased sensitivity for upright PLWs relative to inverted PLWs with a overall difference of 3°. This sensitivity difference disappeared after 1Hz TMS over left-pSTS, with a sensitivity decrease after TMS in both sites irrelevant of orientation. These data provide evidence of a neuronal system tuned towards the angle directions of biological agents. Data suggest that our visual system is optimized for perception of biological motion and shows increased sensitivity f PLW only when presented upright. This ability is selectively impaired after TMS over pSTS, an area implicated in the perception of biological motion.

53.460 **Physical Exercise Reduces the Facing-the-Viewer Bias for Biological Motion Stimuli** Adam Heenan[1](adam.heenan@queensu.ca), Nikolaus Troje[1]; [1]Department of Psychology, Queen's University

Biological motion stimuli, depicted as orthographically projected stick-figure walkers (SFWs), do not contain any information about their orientation in depth: A fronto-parallel projection of a SFW facing the viewer is the same as a facing-away projection. Despite this depth-ambiguity, observers tend to interpret SFWs as facing the viewer more often (Vanrie et al., 2004). Some researchers have speculated that this facing-the-viewer (FTV) bias has a sociobiological explanation: Mistaking an approaching human as retreating when he/she is actually approaching is assumed to be more costly than making the opposite mistake. Indeed, there appears to be support for this, as observers tend to have greater FTV biases for male walkers than for female walkers (Brooks et al., 2008; Schouten et al., 2010). We have also observed positive correlations between anxiety and FTV biases in our lab (Heenan et al., 2012). The goal of this study was to investigate whether physical exercise, which is known to reduce anxiety, would significantly reduce FTV biases for SFWs. We employed a 3 (Stimulus Type: full SFW, bottom-half-only, top-half-only; within-subjects) x 3 (Exercise Condition: standing, walking, or jogging on a treadmill; between-subjects) mixed design. We hypothesized that physical exercise would decrease FTV biases for the full SFWs only, as bottom-half- and top-half-only SFWs carry less sociobiological relevance than full SFWs. Sixty-six participants completed anxiety questionnaires, performed the treadmill task (10 min), and then immediately completed the SFW task. As hypothesized, physical exercise reduced FTV biases for the full SFW stimuli only. Furthermore, anxiety (measured before the treadmill task) was significantly correlated with FTV biases for the standing condition only. Our results suggest that the FTV bias for biological motion stimuli may indeed have a sociobiological basis.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada (NSERC)

53.461 **The effect of movement-complexity on perceived audio-visual synchronicity** Ramona Kaiser[1,3], Carolina Brum Medeiros[2], Marcelo M. Wanderley[2], Marc Schönwiesner[1]; [1]University of Montreal/Canada, [2]McGill University/Canada, [3]Max Planck Institute for Human Cognitive and Brain Sciences/Germany

The Point-Light (PL) technique, which represents a person as a cluster of point lights (PL display), is a common method to investigate the perception of body movements. Observers of such displays can identify, for instance, a performed action, the sex or the identity of the portrayed person (for a review see Blake & Shiffrar, 2007). Petrini and colleagues (2009) investigated observers' sensitivity to audio-visual temporal synchronicity by presenting PL-displays of drumming actions and found that experienced drummers had a higher sensitivity for audio-visual synchronicity than persons without expertise in the performed action. This research raises the question to which extent the perception of audio-visual temporal synchronicity is affected by stimulus characteristics, such as the complexity of the presented information. We measured perceived synchronicity for audio-visual stimuli of different complexity. During three sessions, 16 participants evaluated 84 audio-visual stimuli. Visual stimuli consisted of PL-displays of a single person. The presented movements (foot-tapping, clapping and dancing) varied in complexity. Auditory complexity ranged from a metronome (single sound) to music (multiple sounds). Audio-visual synchronicity was altered by delaying one modality with respect to the other (auditory-leading or visual-leading). Delays ranged from 80 ms to 280 ms, in steps of 40 ms. Each stimulus was presented 28 times across all sessions, and participants were asked to rate the synchronicity of each stimulus on a 6-point scale raning from asynchronous to synchronous. Results indicate an effect of movement complexity on sensitivity to audio-visual synchronicity with significantly higher thresholds for more complex relative to simpler movements. A general advantage was found for auditory-leading, relative to visual-leading stimuli. These findings extend previous research demonstrating that sensitivity to audio-visual synchronicity is affected by movement complexity. Our results contribute to the understanding of the perception of kinematic information and multisensory integration.

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53.462 **Changes in camera elevation dictate perception of point-light walkers' facing direction.** Sophie Kenny[1](kenny.s@queensu.ca), Nikolaus Troje[1,2]; [1]Psychology, Queen's University, [2]Computer Science, Queen's University

The degree of perspective distortion of an object depends on the ratio of its size to its distance from the rendering camera (the field-of-view, FOV). Previously, researchers have reported that sufficient amounts of linear perspective can disambiguate the direction of an otherwise depth-ambiguous point-light display (e.g., Schouten & Verfaillie, 2010). Based on their finding that the effect of FOV on the FTV bias is modulated by the height of the camera above ground Troje, Kenny, and Weech (2013) hypothesised that this observation is not based on linear perspective per se, but rather the result of a bias to see the walker's feet from above rather than from below. Here, we test explicitly if the previously reported effects of linear perspective are caused by camera elevation changes that pit a facing the viewer bias (FTV) against a very strong viewing from above bias. We asked participants to indicate the perceived facing direction of point-light displays, and modified the camera elevation according to a staircase procedure targeting the 25%, 50% and 75% FTV thresholds. A univariate ANOVA showed that camera elevation caused large changes in perceived facing direction at the three FTV bias thresholds: 25% (M = -12.87°, SD = 10.14°), 50% (M = -6.27°, SD = 10.99°), or 75% (M = -1.00°, SD = 8.28°), $F(2, 22) = 16.04$, $p < .001$. Increasing amounts of negative elevation, below the horizontal plane, led to the perception of point-light displays as facing away from the viewer. Most importantly, the resulting psychometric function is identical to those obtained with linear perspective methods that incidentally modify camera elevation (Troje, Weech, & Kenny, 2013). We argue that camera elevation, not linear perspective, produces the previously observed modifications of the facing-the-viewer bias of depth ambiguous point-light walkers.

Acknowledgement: NSERC

53.463 **Breaking Bio: Does biological motion have preferential access to awareness?** Luke E. Miller[1](lumiller@ucsd.edu), David Carmel[2], Ayse P. Saygin[1]; [1]Cognitive Science, University of California, San Diego, [2]School of Philosophy, Psychology, and Language Sciences, The University of Edinburgh

Perceiving biological motion is important for human behaviour and social interaction. Due to its ecological importance, biological motion is believed to be especially salient, but whether and at which stage of processing such "special" treatment occurs is unknown. Here we presented point-light walker (PLW) biological motion stimuli while suppressing them from awareness using continuous flash suppression (CFS). We gradually increased the contrast of the masked stimuli and measured the time it took them to break into awareness (or the contrast needed to breakthrough). To ensure that judgments were orthogonal to the nature of the masked stimuli, subjects reported the location of the PLWs (whether the figure was slightly to the left or right of fixation). In Experiment 1, biological motion stimuli were presented either intact or spatially scrambled, which disrupts the global form of the PLW. We reasoned that faster breakthrough of a stimulus would indicate preferential processing (cf. Yang et al., 2007). Indeed, intact PLWs were perceived 17% faster than their scrambled counterparts. The effect was not due to inherent stimulus differences influencing the target location task since control studies without CFS showed no difference between conditions. In Experiment 2, we manipulated form and motion information in the masked stimuli, presenting intact and spatially scrambled PLWs in upright or inverted orientations. Inversion of intact PLWs reduces global form and disrupts local motion; inversion of scrambled PLWs disrupts both form and local motion. For upright PLWs, we replicated the findings of Experiment 1. We also observed that intact PLWs reached awareness 4% faster when presented upright compared to inverted; no inversion effect was found for scrambled PLWs. Taken together, these studies show preferential processing of biological motion without awareness, and suggest the effect is driven primarily by the coherent form of the stimuli rather than local motion.

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53.464 **Affective Priming by Biological Motion** Edward Nguyen[1](edn002@ucsd.edu), Wayne Khoe[1], Ayse P. Saygin[1]; [1]University of California, San Diego

Emotion is a pervasive and important aspect of human perception and consciousness. Relatively little is known about the mechanisms underlying the perception of emotional body movements, despite its inherent presence and influence in our daily lives. Here, we employed an affective priming paradigm, where subjects were primed with point-light biological motion stimuli (arm movements) conveying anger, happiness or neutral affect (Pollick et al., 2001). They subsequently were asked to make judgments on target words that were either positive or negative in valence. Responses in affectively congruent trials (i.e., happy prime/positive target or angry prime/negative target) were significantly faster than those in incongruent and neutral trials, indicative of a positive priming effect. In a second experiment, point-light displays were spatially scrambled to disrupt the global form of the primes while retaining the local motion cues. No significant difference was found between any of the prime-target conditions, indicating local motion information is insufficient to lead to the affective priming effect. In a third experiment, we prevented the primes from reaching awareness by using a stereoscope. The affective priming effect was abolished when the primes were masked, indicating awareness is necessary for the affective priming effect. On the other hand, we found a main effect of prime type; responses for the happy primes were significantly faster than those for angry or neutral primes. Taken together, these data show that emotion cues conveyed by biological motion modulate the processing of incoming affective stimuli, adding to the literature on both biological motion and affective priming research. Biological motion can influence affective processing even when rendered unconscious, though the higher order priming effects appear to rely on the stimuli reaching awareness. Future work is needed to delineate similarities and differences between conscious and unconscious processing of affective biological motion.

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53.465 **Biological movement and the encoding of approach** Christopher Benton[1](chris.benton@bristol.ac.uk), Martin Thirkettle[2], Nick Scott-Samuel[1]; [1]School of Experimental Psychology, University of Bristol, Bristol, UK, [2]Faculty of Social Sciences, The Open University, Milton Keynes, UK

We investigated the role of biological movement in the encoding of walker-signalled approach. Two stimuli were used: a walking mannequin and an oscillating ovoid, both with chequerboard textures. The ovoid had the same approximate dimensions as the mannequin and oscillated about its minor, horizontal axis at the same frequency as the gait cycle of the mannequin. Stimuli could be rotated in the horizontal plane, with 0° indicating that the mannequin or ovoid directly faced the observer, and positive angles indicating leftwards rotation. Subjects reported whether stimuli headed to their left or their right, and we calculated their angle of subjective approach (ASA). Using an adaptation-top-up method with on-screen adaptors 25% larger than test stimuli, we measured ASAs during adaptation to adaptors angled at -25° and at +25°. Typically, due to adaptor repulsion, -25° adaptation results in a positive ASA whilst +25° adaptation results in a negative ASA. We defined heading aftereffect as half the difference between these two ASAs. When adaptor and test were the same stimulus type we found robust heading aftereffects. When they differed, the aftereffect was abolished – so the aftereffect is not a simple response bias. Next we compared our mannequin heading aftereffects for forward and reversed motion mannequin adaptors. All test sequences were standard forward motion. Both forward and reversed adaptors elicited robust aftereffects, with the latter significantly weaker. Finally, we measured direction contingent heading aftereffects by adapting subjects to interleaved segments of forwards mannequin at -25° and reversed mannequin at +25° (and vice versa). We found that heading aftereffects were contingent upon the direction (forward or reversed) of the test stimulus. Our results show that, beyond influences such as body orientation and direction of limb trajectory, the actual biological motion itself factors into the percept of direction in our encoding of approach.

Acknowledgement: British Academy

53.466 **Unconscious Processing of Biological Motion** Ayse P. Saygin[1](asaygin@ucsd.edu), Chen Song[2], Bianca van Kemenade[3], Luke E. Miller[1], Geraint Rees[2], Bahador Bahrami[2]; [1]Department of Cognitive Science, University of California, San Diego, [2]Institute of Cognitive Neuroscience, University College London, [3]Berlin School of Mind and Brain, Humboldt-Universität zu Berlin

Biological motion processing is critical for survival and social interaction, but whether processing of these stimuli can take place outside awareness is unknown. Point-light biological motion stimuli consisting of about a dozen markers attached to the limbs of an actor have been used for decades to study the perception of biological motion. Here, we investigated whether point-light walker (PLW) stimuli masked and rendered invisible by interocular suppression could nevertheless induce adaptation for subsequent unmasked target PLWs. In each trial, an adapter PLW was presented to one eye and a large number of moving dots to the other; when fused, the noise dots effectively mask the PLW. Observers were then presented with an unmasked target PLW and were asked to report as fast as pos-

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sible the direction in which it is facing. In Experiment 1, we established that discrimination of the direction of consciously perceived PLWs was faster if they were preceded by a masked adapter PLW heading in the opposite direction, indicating unconscious biological motion stimuli could induce adaptation. In Experiment 2, we replicated and extended this result by showing that the effect depended on adapter duration. Whereas single frame (12ms) or 300 ms PLWs did not induce significant adaptation, 600 ms and 2350 ms invisible PLWs did. Control studies were administered for each experiment to ascertain the adapter PLWs were not consciously perceived by the observers. Overall, these data show that masked biological motion still receives processing, and more specifically, that adaptation for biological motion can occur outside of awareness.

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53.467 **Fundamental constraints in perceiving socially interactive traits without human form** Steven Thurman[1](sthurman@ucla.edu), Hongjing Lu[1,2]; [1]Department of Psychology, UCLA, [2]Department of Statistics, UCLA

It is vitally important for humans to quickly detect living creatures in the environment, and to analyze their behavior to facilitate action understanding and high-level social inference. The current study examined the ability of human observers to spontaneously perceive complex social behaviors using spatially-scrambled point-light displays of human social interaction. Specifically, we investigated the importance of global form information, intrinsic joint movements, extrinsic whole-body movements, and critically, the congruency between intrinsic/extrinsic motions. Motion congruency provides an important theoretical constraint on biological motion due to the causal relationship between limb movements and the direction of global body motion. In Experiment 1, we discovered using a free response paradigm, that even for spatially-scrambled point-light displays from which global human form has been removed, naïve observers (55%, n=37) spontaneously reported animate/social traits in various displays that originated from social interactions (e.g. dancing, tug-of-war, high-five). However when congruency between intrinsic/extrinsic motion was violated, observers were less likely to infer socially interactive traits (37%, n=27), and were more likely to attribute physical/mechanical traits. Experiment 2 showed that observers (n=33) could accurately discriminate meaningful interaction in spatially-scrambled displays of human salsa dance (2IFC task), as long as congruency was maintained between intrinsic and extrinsic motion. Violating this constraint resulted in chance performance. In Experiment 3, observers (n=10) rated the degree of interactivity (scale 1-5) between spatially-scrambled salsa dancers. Stimuli that violated the motion congruency constraint were consistently rated as less interactive than congruent displays, regardless of whether the dancers were truly engaged in meaningful interaction or not. These results suggest a hierarchical system in which basic filters first operate to detect animate creatures based on a set of fundamental constraints (e.g. gravity, motion congruency, body structure). Only if these constraints are satisfied, higher-level processes would be engaged to support action understanding and social inference.

53.468 **Perceived animacy influences other forms of visual processing: Improved sensitivity to the orientations of intentionally moving objects** Benjamin van Buren[1](vanburenb@gmail.com), Brian Scholl[1]; [1]Department of Psychology, Yale University

For decades, work on perceived animacy has emphasized that the currency of perception consists not only of simple features such as color and shape, but also seemingly higher-level properties such as intentionality and goal-directedness. This work has typically been treated as an endpoint of perception, but here we explore how perceiving intentions may interact with other aspects of visual processing. In particular, we demonstrate that when an object is seen to move intentionally, observers perceive its orientation with greater precision. We made use of the wolfpack effect: if a moving object remains oriented toward a particular target over time, observers will perceive its motion as intentional (e.g. as chasing) — even if its actual movements are random. In a detection task, observers viewed a moving disc sporting two dots that were perceived as eyes. The disc moved randomly, facing toward or away from another 'target' shape. Observers had to detect when (on half of trials) this 'facing' regularity became broken, such that the disc began rotating independently. Perceived intentionality boosted orientation processing: observers were more sensitive to the disc's rotation when it initially faced the target. This improvement also occurred in a reproduction task, with a task-irrelevant target. On each trial, observers viewed a randomly moving shape facing toward or away from (or independent of) a moving target. Unpredictably, both the target and the shape's orientation cue disappeared, the shape stopped moving, and observers had to reproduce the shape's final orientation. Responses were more accurate on trials where the shape faced the target, compared to when it faced away or rotated independently. Thus intentional motion improves orientation sensitivity even when the visual cue to intentionality is incidental. Collectively, these experiments demonstrate that the perception of intention from motion interacts with other visual processes in rich and hitherto unknown ways.

53.469 **Stick figures and point-light displays: Effects of inversion on the facing-the-viewer bias** Séamas Weech[1](seamas.weech@queensu.ca), Nikolaus F Troje[1]; [1]Department of Psychology, Queen's University, Kingston, Canada

Depth-ambiguous point-light walkers are most frequently seen as facing-the-viewer (FTV). Inverting the figures considerably reduces this FTV bias (Vanrie et al., 2004). The finding has been used to argue that the FTV bias depends on recognizing the stimulus as a person – which is more difficult when the stimulus is inverted. Recent experiments indicate that the FTV bias is largely caused by a bias to perceive depth-ambiguous surfaces as convex (Weech and Troje, 2013). Based on this research, we hypothesized that the effect of inversion on FTV bias arises due to the difficulty with which coherent 3D shape is resolved from inverted point-light walkers. Without this shape, the stimulus appears 'flat' and the convexity bias does not play out. If explicit, coherent shape is provided (as in stick figures) we would expect no effect of inversion on FTV bias. We measured the FTV bias in 30 participants for upright and inverted point-light walkers and stick figures. We depicted stimuli at frontal and three-quarter views and recorded observers' perceived facing directions. We defined the FTV bias as the percentage of responses signaling a facing-towards interpretation. Participants accurately chose one of the two veridical interpretations at a rate of over 95% for both stimulus types. We found an interaction between stimulus representation and orientation: The inversion effect for stick figures (44%) was smaller than that for point-light walkers (55%). This result supports our hypothesis to a limited degree. Unexpectedly, both stimulus types generated reliable facing-away bias when inverted. Results are consistent with the hypothesis that the lower part of the stimulus takes precedence when subjects are making judgments of facing directions, given that the knees and elbows are opposing in terms of the facing direction implied when assumed to be convex.

Acknowledgement: This research was funded by grants from NSERC and CIfAR to NFT.

Attention: Spatial selection

Tuesday, May 20, 8:30 am - 12:30 pm
Poster Session, Pavilion

53.501 **Spatial Cueing of Infants' Selective Attention, Target Selection and Eye Movements** Audrey Wong Kee You[1](audwky@yorku.ca), Scott Adler[1,2]; [1]York University, [2]Centre for Vision Research

On a daily basis we experience an overabundance of environmental information. In order to overcome our limited amount of attentional resources, particular items in space must be selected as targets. For infants, attentional resources are even more limited. Models of attention have proposed that resources are restricted to particular spatial locations, enhancing processing at these locations. Evidence for selection due to spatial attention has been provided by studies that use a spatial cueing paradigm, in which attending to the particular location indicated by a preceding cue results in faster and more accurate selection of, and eye movements to, items presented at that location compared to when no cue is presented. Whether infants exhibit similar spatial attention and target selection mechanisms has yet to examined. To this end, in this study, 3-month-old infants were presented with either no cue or with a 150 msec cue to either the right or left of fixation indicating the subsequent location of the target to which they should make an eye movement. Then, either one stimulus or two stimuli (one target and 1 distractor) were presented at 5° from fixation and the latency of infants' eye movements was measured to the one of the stimuli or to the cued target. Results have indicated that, consistent to findings with adults, presentation of the spatial cue resulted in a facilitation of target selection as exhibited by a decrease in infants' eye movement latency. These results were also found when a distractor was presented with the target. Infants' eye movement latencies, however, were much slower than typically found in studies with adults. This finding suggests that the mechanisms responsible for the allocation of spatial attention in guiding target selection is functioning in early infancy. Yet, these mechanisms require further development to reach full efficacy.

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53.502 **Different spatial attention for different stages of visual processing** Satoshi Shioiri[1,2](shioiri@riec.tohoku.ac.jp), Hajime Honjo[2], Kazumichi Matsumiya[1,2], Kuriki Ichiro [1,2]; [1]Tohoku University(Research Institute of Electrical Communication), [2]Tohoku University(Graduate School of Information Sciences)

Hidden formatting deleted. Delete this text! none;text-autospace:none">[Purpose] We previously compared two types of EEG components, steady-state visual evoked potential (SSVEP) and P300 of event-related potential (ERP), and found that the two measures showed different spatial characteristics: SSVEP showed broad spatial tuning while P 300 showed narrower one. It might be the case that different stages of visual processing have different spatial aspects of visual attention. To investigate the stage differences of visual attention, we compared the spatial spreads of visual attention with different tasks assigned as dual tasks: letter identification and luminance change detection. Hidden formatting deleted. Delete this text! none;text-autospace:none">[Method] The observer attended to one of eight circularly arranged disks to detect targets as the primary task in the rapid serial visual presentation sequence, ignoring stimulus at other locations. The secondary task was to detect luminance decrement at either of eight disks during 6s of stimulus presentation. We recorded manual responses for the two tasks and EEG signals to analyze ERP and SSVEP components: ERP for target presentations for both tasks and SSVEP for eight disks that have luminance flicker with different temporal frequencies. We obtained spatial tunings of attention modulation by change in performance or EEG amplitude (SSVEP or P300) as a function of distance from the focus of attention along the circular path. Spatial spread of visual attention was estimated for each of the four measures separately. Hidden formatting deleted. Delete this text! none;text-autospace:none">[Results] Spatial spread was broader for SSVEP than for P300 and was broader for luminance detection than for letter identification. They suggest that spatial characteristics of visual attention differ for different stages of visual processing. Visual attention may spread more broadly at early visual stages than at later stages.

53.503 **Within-participant differences in attention-related shifts in contrast response functions measured using EEG and fMRI** Thomas Sprague[1](tsprague@ucsd.edu), Sirawaj Itthipuripat[1], John Serences[1,2]; [1]Neurosciences Graduate Program, University of California, San Diego, [2]Department of Psychology, University of California, San Diego

Single-unit electrophysiological studies have demonstrated that attention could result in several different modulations of the contrast response function (CRF) measured in visually responsive neurons: contrast gain (the CRF shifts leftward), response gain (the multiplicative gain factor increases) and additive shift (the CRF moves upwards by a constant amount). Yet, decisions made about visual stimuli are likely based on population-level responses. Attentional modulation of CRFs, measured using population-level techniques such as fMRI or steady-state visually evoked potentials (SSVEP) in EEG, have uncovered conflicting patterns of gain modulation. When measured using fMRI, attention results in a purely additive increase in CRFs (Buracas & Boynton, 2007; Murray, 2008; Pestilli et al, 2011). However, SSVEP CRFs exhibit either response gain or contrast gain (Kim et al, 2007; Lauritzen et al, 2010; Itthipuripat et al, in press). So far, it is unclear whether the difference in gain pattern between fMRI and EEG is due to the differing modulation of the vascular and electrophysiological responses or due to the fact that results were obtained across different participants and tasks with differing stimulus properties. Here, we conducted a study where CRFs were measured using fMRI and SSVEP from the same participants using an identical spatial attention task. We found that attention primarily enhances the additive gain in the hemodynamic CRF but results in either response or contrast gain in the SSVEP CRF, depending on the participant. Furthermore, we used a multivariate spatial encoding model analysis with fMRI data (Sprague & Serences, 2013) to reconstruct spatial representations of the stimulus display and found a spatially selective enhancement of stimulus representations with attention. Together, these results suggest that local pooling reflected in hemodynamic responses masks response or contrast gain patterns with attention that can be well-characterized using large-scale electrophysiology which constrains inferences that can be made using each method.

Acknowledgement: NIH R01-MH092345, James S McDonnel Foundation Scholar Award NSF GRFP

53.504 **New rules for visual attention selection** Mahalakshmi Ramamurthy[1](zz.maha@gmail.com), Erik Blaser[1]; [1]Department of Developmental and Brain Sciences, Human Vision Laboratory, University of Massachusetts, Boston

The selective processing of visual information, through attention, is based on bottom-up biases and top-down intentions. Here we sought evidence for a third way, through learned rules that are implemented automatically, without cognitive supervision; what we term 'dark attention'. Methods: Our main goal was to find evidence for selection in the absence of bottom-up demands and top-down intentions. We used the duration of the motion aftereffect (MAE) as a passive assay of selective resource allocation. In our main condition, observers saw two superimposed fields of limited-lifetime isoluminant dots, green and red, moving coherently to the left and right, respectively. Such a stimulus is physically balanced and should yield no net MAE (as tested by a static test field of red/green dots), unless the observer selectively attends during adaptation. In our attempt to train a new selection rule, eight observers participated in a three-day training paradigm where they explicitly attended to the red field (encouraged through a direction detection task on the attended field – in this case the red field). Before training, MAE's were measured while observers were asked to perform an auditory two-back memory task (a distracting task aimed at disrupting top-down selection); MAE's were minimal as expected (Mean: 0.37 s; SE: 0.10). Following training, observers were retested in that same condition. Results: Even though the red and green fields were balanced (sidestepping bottom-up selection), and even though observers were again distracted by the two-back task (preventing top-down selection), the red field was still being selected: MAE's were significantly increased (Mean: 2 s; SE: 0.47; two-tailed t-test =-3.45; p= 0.01). This shows that resources were deployed automatically (while distracted observers were presented with physically balanced stimuli), and training induced a new rule for selection.

53.505 **Probability Cues Enhance Perceptual Estimations** Syaheed Jabar[1](syaheed.jabar@uwaterloo.ca), Britt Anderson[1,2]; [1]Department of Psychology, University of Waterloo, [2]Centre for Theoretical Neuroscience, University of Waterloo

Stimulus probabilities affect detection performance: Rare targets, even if important (e.g. bombs, abnormal medical scans, etc.), are missed more often than their higher-probability counterparts. To minimize such probability-related costs, there is a need to understand how probability expectations develop and how they interact with attentional and perceptual processes. A previous experiment demonstrated that observers made smaller judgement errors when estimating orientations of exogenously-cued versus non-cued spatial gabors, suggesting that attentional deployment affects perceptual representations of target stimuli. Using the same paradigm, but with endogenous probability cuing (e.g. having right-positioned gabors likely being right-tilting), we replicated the effect: In Experiment 1a, observers were more precise (i.e. made smaller errors and had a more kurtotic distribution of angular errors) in their estimates for high-probability tilts than low-probability tilts. In Experiment 1b, where different probability distributions were conditionally cued (i.e. having the position-to-probability relation dependent on cue colour), the kurtosis measure again differentiated observers' performance between orientation probabilities. Across both experiments, changes in kurtosis rapidly developed despite observers not being instructed on the underlying probability distributions. Curiously, observers were also more precise when judging gabors with near-vertical rather than near-horizontal orientations, while simultaneously displaying judgement errors that were systematically skewed towards the vertical rather than the horizontal meridian. These findings on kurtosis and 'vertical-bias' coalesce in Experiment 2, which tested graded probabilities instead of a binary high/low probability distinction. Particularly, there appears to be a synergistic effect of having near vertical-tilts on the kurtosis measure for higher versus lower-probability tilts. In short, endogenous probability cuing, even if relatively complex, results in behavioral performance closely aligned to what one would expect from traditional 'attentional' manipulations such as exogenous cuing. Possibly, the learning of stimulus probabilities might interact with pre-existing perceptual biases to weight perceptual processing towards expected targets and/or away from less expected targets.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada (NSERC)

53.506 **Attentional ambiguity and feature binding errors** Julie Golomb[1,2](golomb.9@osu.edu); [1]Department of Psychology, The Ohio State University, [2]Center for Cognitive and Brain Sciences, The Ohio State University

Spatial attention is thought to play a critical role in feature binding. However, there are often multiple objects or locations of interest in our environment, and we need to switch or split attention between them. How do

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these "attentionally ambiguous" scenarios affect the binding process? Here we show that binding is altered in both cases, but switching vs splitting attention result in different types of feature binding errors. We used a continuous report color perception task where subjects were pre-cued with a location(s) to attend, and then presented with an array of four colored squares. The task was to report the color at the attended location by clicking on a colorwheel. In the Attention-Switching experiments, we cued subjects to shift attention to a second location before the colors appeared. When the color stimuli were presented shortly after the switch cue, "swapping" errors were prominent, with subjects sometimes misreporting the color that appeared at the initially cued location. After longer delays (>500ms), the swapping errors diminished back to chance levels. In the Attention-Splitting experiments, subjects received two simultaneous cues and were instructed to attend to both locations; only after the colors appeared were they instructed which location to report. Here we found no evidence of swapping errors, but we instead found "mixing" errors: subjects tended to report a color that was a subtle mix of the target color and the color at the other attended location. Interestingly, in another version we varied the distance in color space between the attended colors: with large differences in color we replicated the mixing result, but with small color differences we found repulsion. We suggest that "swapping" and "mixing/repulsion" errors stem from different attentional mechanisms: incomplete updating of attention results in swapping errors, whereas mixing/repulsion errors occur when two locations are simultaneously sharing attentional resources.

53.507 **The change probability effect for high and low spatial frequency items accompanied by a shift in the allocation of attention during encoding** Melissa R. Beck[1](mbeck@lsu.edu), Amanda E. van Lamsweerde[2], Rebecca R. Goldstein[1], Justin M. Ericson[1]; [1]Louisiana State University, [2]North Dakota State University

The change probability effect occurs when probable changes are detected more accurately than improbable changes (Beck, Angelone, & Levin, 2004). This effect occurs for familiar everyday objects and can be the result of incidentally learned change probability information for novel objects. The change probability effect has been attributed to biases at the retrieval and comparison stages (Beck et al., 2007) and the decision stage (Yange, Chang, & Wu, 2013). The current study examined whether participants could learn that changes to either high spatial frequency (HSF) or low spatial frequency (LSF) items were more probable and then use this information to bias attention during encoding. Participants were shown arrays of six Gabor patches, three HSF and three LSF, oriented 45° to the left or the right. After an 800ms presentation of the study array, a test array was presented in which one of the patches changed orientation. Participants indicated which of the six items had changed. For half of the participants, HSF items changed on 80% of the trials (HSF probable condition) and for the other half, the LSF items changed on 80% of the trials (LSF probable condition). When possible, the HSF item that changed was an item fixated during study, and the LSF item that changed was an item that was not fixated during study. Participants completed 3 blocks of 40 trials. In the HSF probable condition, performance improved across blocks for HSF changes, but not for LSF changes. In the LSF probable condition, performance improved across blocks for LSF changes, but not for HSF changes. In addition, the amount of time participants spent looking directly at items decreased across blocks for the LSF probable condition, but not for the HSF probable condition, demonstrating a shift in the allocation of attention across blocks in the LSF probable condition.

53.508 **Measuring the attentional suppressive surround** Sang-Ah Yoo[1, 5](sangahy@yorku.ca), John K. Tsotsos[2, 5], Mazyar Fallah[3, 4, 5]; [1]Department of Psychology, York University, [2]Department of Electrical Engineering & Computer Science, York University, [3]School of Kinesiology and Health Science, York University, [4]Canadian Action and Perception Network, York University, [5]Centre for Vision Research, York University

The Selective Tuning (ST) model (Tsotsos, 1995) proposed that there is a suppressive zone surrounding the spatial focus of attention. Follow-up studies suggested behavioural and neurophysiological evidence for the attentional suppressive surround (Cutzu & Tsotsos, 2003; Hopf et al., 2006). The model also predicts that the size of the suppressive surround is determined by the receptive field size of the attended neuron. According to this prediction, we hypothesized that the size of the suppressive surround would change by the level that best represents the attended stimulus in the processing hierarchy. We conducted a visual search task to verify this hypothesis and used three different types of features processed at different levels, respectively – orientation, curvature (Pasupathy & Connor, 1999), and 3D shape (e.g. greebles, Gauthier & Tarr, 1997). We tracked participants' eye movements during visual search to find rapid return saccades from a distractor to a target. We hypothesized that return saccades suggest the release of the target from the suppressive surround of the nearby attended distractor (D1) (Sheinberg & Logothetis, 2001). The eye movement from D1 to another distractor (D2) moves the suppressive surround towards the same direction of that eye movement. Hence, a target is eventually perceived and the return saccade from D2 to the target occurs. We measured the distance between the target and D1 when the return saccade occurred and it represented the size of the suppressive surround. The minimum distance between each stimulus systematically varied as an independent variable. We observed that the size of the suppressive surround increased as the level of the attended feature becomes higher. Therefore, greebles formed the largest suppressive surround, curvature formed the second largest, and orientation formed the smallest one. This result further demonstrates the suppressive surround and provides supporting evidence for ST's prediction for the size of the suppressive surround.

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53.509 **Spatial Negative Priming: Location or Response?** W. Trammell Neill[1](neill@albany.edu), Abigail L. Kleinsmith[1]; [1]Department of Psychology, University at Albany, State University of New York

If a stimulus is ignored, responses to a subsequent similar stimulus may be slowed (Neill, 1977; Tipper, 1985). Such "negative priming" can also apply to the location of an ignored stimulus in a target localization task (Tipper, Brehaut & Driver, 1990). In most demonstrations of spatial negative priming, there is a one-to-one correspondence of locations to responses. Consequently, it is ambiguous whether the suppression occurs for processing at a specific location, or for the response associated with that location. Some experiments suggest location suppression (e.g., Neill, Valdes & Terry, 1992), others suggest response suppression (e.g., Buckolz, Goldfarb & Khan, 2004). However, most experiments were designed to test only for one effect or the other. In the present experiment, subjects responded to the ordinal position of a target in one of four marked locations. On "prime" trials, an irrelevant distractor appeared at another location. Crucially, the display widths were varied, such that the inner two positions of "wide" displays coincided with the outer two positions of "narrow" displays. Thus, a "probe" target could appear in the location of the prime-trial distractor, but require a different response; or, a probe target could appear in a location different from the distractor, but require the same response. BOTH conditions yielded slower RT than control trials in which the probe target was unrelated to the prime-trial distractor or target. Ergo, spatial negative priming has BOTH location-specific and response-specific components.

53.510 **The order of attentional shifts determines what visual relations we extract** Audrey L. Michal[1](audrey.lustig.michal@northwestern.edu), Steven L. Franconeri[1]; [1]Department of Psychology, Northwestern University

According to one recent account, judging spatial relations (e.g., a small blue object to the left of a large red one) is based on ordered attentional shifts. This account predicts that spatial relations are represented asymmetrically; knowing that the left, blue object is smaller is distinct from knowing that the right, red object is larger. However, evidence for the importance of this 'directionality' in judging spatial relations is missing. Here we confirm the surprising prediction that the order of attentional shifts has a powerful impact on the direction of the extracted relation. Participants were eyetracked while they made speeded responses to questions of the type "Is the red object larger than the blue object?" For this question, we predicted faster responses when the order of attentional selection started with the red (first mentioned) object, producing a representation of 'red larger'. In an undergraduate population, we found exactly this: the more individuals selected the first mentioned object first, the faster their RTs were (R^2=0.30). A strategy of systematically selecting the left or right object first (ignoring question order) was less prevalent and unrelated to RT. Given that undergraduates are well-trained in extracting relations, we tested a second population that might reveal individual differences: 8-year old children. Again, RT was faster for participants who regularly inspected the first mentioned object first (R^2=0.41). Surprisingly, more children adopted a strategy of selecting the left object first, regardless of the question – these participants tended to be slower (R^2=0.32). We observed both optimal (selecting the first mentioned object) and sub-optimal routines (selecting the left object) for extracting visual relations, with children showing a greater tendency to attend sub-optimally. The order of attentional shifts accounted for a significant amount of variability in RT and thus appears critical for framing 'directionality' of visual relation representations.

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See page 3 for Abstract Numbering System

53.511 **Salience Across Spatial Scales** Calden Wloka[1,2](calden@cse.yorku.ca), Nicholas Frosst[3,4], John Tsotsos[1,2]; [1]Department of Electrical Engineering and Computer Science, York University, [2]Centre for Vision Research, York University, [3]Department of Computer Science, University of Toronto, [4]Department of Cognitive Science, University of Toronto

Saliency algorithms predominantly utilize a winner-take-all (WTA) approach to determine fixation targets. However, WTA methods are vulnerable to spike noise, and thus most algorithms will employ a smoothing step over the initial saliency map in order to improve the signal-to-noise ratio (SNR). Although it is common practice to plot the performance of a given saliency algorithm as it varies with the size of this smoothing kernel in order to find the overall optimal degree of smoothing (see Hou et al. 2012 for an example), we show that there remains variability in the optimal degree of smoothing between individual images. We propose an algorithm for projecting a saliency map across multiple spatial scales and dynamically determining the most appropriate scale from which to select a fixation target. This not only provides a mechanism for improving the performance of most saliency algorithms, but also links saliency research to a number of important psychophysical results in the area of visual search. As Wolfe (1998) has previously described, there are a large number of dimensions underlying efficient visual search beyond those ordinarily covered by saliency algorithms (which typically focus on orientation and colour); our algorithm explicitly allows for spatial scale to be incorporated into the salience calculation. Likewise, Najemnik and Geisler (2005), demonstrate that an optimal observer in a visual search task executes fixations based both on WTA strategies and what they label Center-of-Gravity (CoG) strategies. By identifying spatial scales in which a number of localized saliency peaks may be smoothed together to form a more unique centralized peak, we provide an implicit mechanism for generating CoG style fixations.

Acknowledgement: NSERC, Canada Research Chairs Program

53.512 **Effects of Feature and Categorical Similarity on the Time Course of Spatial Attention** Jeongmi Lee[1](jeongmi0123@gmail.com), Joy Geng[1]; [1]Center for Mind and Brain, University of California Davis

Attention to an exogenously cued location is initially facilitated and then inhibited (Posner and Cohen, 1984). However, it remains unclear how the time course of spatial attention interacts with feature-based attention. Here, we investigated the effect of cue-to-target feature similarity on spatial and temporal attentional allocation. A variant of the Posner cueing paradigm was used where cue and probe circles were presented at varying inter-stimulus intervals (ISIs) (50, 150, 350, 700ms) in random locations (left, right). The colors of the cue and the probe were chosen from four evenly distributed colors (orange, yellow-orange, orange-yellow, yellow). Subjects responded to the location of a target-colored (orange or yellow, counterbalanced) probe, and withheld responses for other-colored probes (catch trials). The portion of catch trials was 10% in Experiment1 (N=18), and 50% in Experiment2 (N=18). In Experiment1, there was an interaction between cue-color and ISI. For target-similar cues (e.g., orange and yellow-orange cues for orange targets), the amount of attentional facilitation in the cued location decreased as ISI increased, but never switched to the uncued location, even at the longest ISI. This was in contrast to inhibition-of-return (IOR) effects observed in a control experiment. For target-dissimilar cues (e.g., yellow and orange-yellow cues for orange targets), there was no facilitation for the cued location early on, and the magnitude of facilitation in the uncued location increased with ISI as a function of the physical and categorical similarity between the cue and the target. In Experiment2, similar effects were found for target-similar cues, but now subjects became more sensitive to target-dissimilar cues. This resulted in facilitation in the uncued location even at the shortest ISI, indicating greater attentional suppression of target-dissimilar cues. These results suggest that the feature and categorical similarity between the cue and the target dynamically interact with the time course of spatial attention.

53.513 **How implicit spatial cues affect attentional orienting: Timing is everything** Alison Chasteen[1](chasteen@psych.utoronto.ca), Davood Gozli[1], Katia Martin[1], Jay Pratt[1]; [1]Department of Psychology, University of Toronto

Concepts with implicit spatial meaning (e.g., "hat", "shoes", "attic", basement") can bias visual processing along the vertical spatial domain. While some studies show directional words interfere with visual processing at congruent locations, due to occupying the same spatial code (Estes, Verges, & Barsalou, 2008), other studies show that directional words facilitate visual processing at congruent locations, due to a spatial bias congruent with the word (Chasteen, Burdzy, & Pratt, 2010). We recently proposed a reconciliation, suggesting that interference and facilitation represent two temporal stages of the same type of processes (Gozli, Chasteen, & Pratt, in press). The present study further tests this proposal using a variant of the additional singleton paradigm (Theeuwes, 2010). Participants read two sequentially presented words (a context word, followed by a directional "cue" word) at the center of the display and then, after some delay, were presented with the search task. The search involved reporting the orientation of the line inside the shape singleton (square among circles) while ignoring the luminance singleton (brighter circle). When there was a short delay, directional words interfered with processing targets at the congruent location, suggesting that the spatial code implicit in the word becomes temporarily unavailable for concurrent visual processing. By contrast, when there was a long delay, directional words both facilitated processing of targets at the congruent location and increased the cost of an irrelevant salient distractor at that same location, suggesting a lingering spatial bias congruent with word meaning. These results support the role of spatial processing in conceptual understanding (Barsalou, 1999), while also revealing the important role of timing when examining the interaction between conceptual and perceptual tasks.

53.514 **Encoding suppression: Linking spatial cueing costs to the attentional blink** Hui chen[1](psychenhui@gmail.com), Brad Wyble[1]; [1]Psychology Department, Pennsylvania State University

Spatial cueing and the attentional blink are two well-known effects that have been extensively investigated. Each of them has been separately explained by various theories. In the present study, we established a common explanatory framework for these two seemingly disparate phenomena in terms of encoding suppression theory. Specifically, we employed a typical spatial cueing paradigm in which a cue (valid, invalid, or neutral (no cue)) appeared before a target letter and asked participants to report the target but ignore the cue. In addition, we systematically manipulated the SOA (100, 200, 300, 500, and 700ms) between cue and target. The results showed that participants performed much worse in invalid than in neutral conditions at 100ms SOA, and this effect disappeared when the SOA increased to 200 ms or longer. Another series of experiments from our lab demonstrated that subjects encoded the location of a cue even when asked to ignore it. Therefore, we suggest that the cue location was automatically encoded into memory and this encoding suppresses attention, which impairs the report of a subsequent target as suggested by models of the attentional blink (Bowman & Wyble 2007). We tested this theory by asking participants to report the location or color of a cue (T1) as well as the target letter (T2) and found that asking subjects to report location produced no additional cost relative to ignoring a cue. However, reporting the color of a cue decreased the ability to report T2, which is consistent with the encoding suppression theory. Furthermore, we increased the difficulty of cue encoding with a mask and found that the encoding suppression effect was strengthened and prolonged which is consistent with attentional blink theories. In conclusion, the present study provided convergent evidence that encoding suppression may underlie both spatial cueing costs and the attentional blink.

53.515 **Grouping processes facilitate prioritization of relevant and suppression of irrelevant information: Behavioral and neurophysiological evidence** Tobias Feldmann-Wüstefeld[1](tobias.fw@gmail.com), Anna Schubö[1]; [1]Philipps-University Marburg

Visual search efficiency depends on both prioritization of relevant and suppression of irrelevant information. Context homogeneity has been identified as one factor that determines search efficiency. It has been argued that pre-attentive grouping may account for accelerated search because it allowed for processing of larger perceptual units. In a series of studies we investigated how grouping affects processing of targets and suppression of distractors. We used a spatial cueing task in which cues and targets were presented in contexts of varying homogeneity. When targets were presented at cued locations (valid trials), performance was best throughout all ISIs used. At short ISIs, when targets were presented at non-cued locations, performance was better when presented within the same context (invalid-inside trials) than when presented within a different context (invalid-outside trials). This context advantage was only observed when contexts were homogeneous, suggesting that sufficiently homogenous contexts were processed as one perceptual unit. In a follow-up study we investigated whether grouping does not only enhance prioritization of relevant, but also suppression of irrelevant information. Prioritization of targets and concurrent suppression of salient distractors was disentangled by using subcomponents of the attention-indicating N2pc in the ERP. The target-elicited NT component showed faster and more pronounced attention allocation for targets in homogeneous than in heterogeneous contexts. The distractor-elicited PD showed delayed distractor suppression in heterogeneous contexts and attentional capture by the distractor in heterogeneous, but not in homogeneous contexts. In sum, the present results show that pre-attentive grouping facilitates target processing and distractor suppression and suggest that goal-oriented processing is less vulnerable to interferences from potentially distracting low-level features in homogeneous contexts.

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53.516 Effects of visual attention on perceptual and movement performance during saccade preparation

Tobias Moehler[1](Tobias.Moehler@psychol.uni-giessen.de), Katja Fiehler[1]; [1]Experimental Psychology, Justus-Liebig-University Giessen, Germany

Previous studies suggest that visual attention is bound to the location of a saccade target during saccade preparation and cannot be withdrawn even when the time to prepare the saccade is extended. However, there is also evidence that attention can be deployed to multiple target locations during the preparation of sequential movements or during the preparation of a movement and a visual discrimination task. Moreover, it is yet unclear whether attentional deployment in space also affects movement parameters. The aim of the present study was to investigate the effects of attentional allocation in space on perceptual and movement performance by employing a modified dual-task paradigm. Participants performed a rapid visual discrimination task at one of three cued locations while preparing a saccadic eye movement to the same location (spatially congruent trial) or a different location (spatially incongruent trial). In addition, saccade preparation time was varied between 0ms and 500ms. Our results showed enhanced perceptual performance in the discrimination task for spatially congruent compared to incongruent trials; however, perceptual performance in incongruent trials was clearly above chance level. Movement preparation time did not affect performance in the perceptual task. Saccade performance, measured by latency, accuracy, and precision, deteriorated in incongruent trials. As expected, saccade latency decreased with increasing movement preparation time. Importantly, for saccadic curvature, a measure which is sensitive to the spatial deployment of attention, we found that saccades curved away from the location of the discrimination target in incongruent trials. Our findings suggest that visual attention is not obligatorily bound to the saccade target, but can be divided upon the discrimination and the saccade target if they appear at different locations in space resulting in costs for perceptual and movement performance.

Acknowledgement: DFG IRTG 1901

53.517 Holding on to the local: Hand posture biases local processing

David Chan[1](davidyt.chan@mail.utoronto.ca), Davood Gozli[1], Jay Pratt[1]; [1]University of Toronto

Placing the hands near visual stimuli produces differences in visual processing compared to when the stimuli are far from the hands. One account for these differences hypotheses that hand-proximity increases the contribution of the magnocellular (M) pathway, while reducing the contribution of the parvocellular (P) pathway (e.g., Chan et. al., 2013). Since the P pathway, which predominately provides the input into the ventral visual stream, supports the grouping of perceptual elements, a strong test of the M/P account of hand proximity can be conducted by examining changes in the processing of local and global features brought about by hand posture. To accomplish this, we presented participants with Navon arrow cues (a large arrow made up of smaller arrows), whose local and global features either pointed in the same or opposite directions. After each arrow there was a variable delay followed by a peripheral target either to the left or the right of the arrow. Participants performed a localization response to these targets as quicker localization reaction times would indicate whether the local or the global information dominated visual processing. In addition, the experiment was conducted in two counterbalanced blocks; one with the participants' hands on the monitor near the stimuli and the other with their hands on the keyboard far from the stimuli. We found an overall stronger local bias when the hands were near the display and a stronger overall global bias when the hands were far from the display. Moreover, global processing persisted longer (i.e., the global to local transition occurred at a longer delay) when the hands were near the stimuli. These findings support the hypothesis that near hands bias the M pathway and hands far bias the P pathway.

Acknowledgement: NSERC

53.518 Hand position increases visual processing for task irrelevant flankers.

William Bush[1](william-bush@uiowa.edu), Shaun Vecera[1]; [1]Psychology, College of Liberal Arts and Science, University of Iowa

Previous research has indicated that hand position impacts visual processing in a manner similar to, and perhaps mediated by, spatial attention. These near hand effects include preferential processing in detection tasks, changes in spatial and temporal sensitivity, and increased attentional dwell time (Reed, Grubb, & Steele, 2006; Gozli, West, & Pratt, 2012; Abrams, Davoli, Du, Knapp, & Paull, 2008). In the current study we wish to determine whether preferential processing in the graspable space of the hand occurs automatically for stimuli that are not critical to performing the task. To demonstrate this we used a flanker paradigm with a central discrimination task. Two peripheral flanking items were included. One flanker item appeared in the graspable space of a raised hand and the other flanker item on the opposite side of the screen from the hand. Each trial included one neutral flanker and one critical flanker. The critical flanker could be either congruent or incongruent with the central target. When the critical flanker was in near-hand space, we found an effect of congruency such that response times (RTs) were faster when the flanker was congruent compared to incongruent, $F(1,29) = 12.6$, $p = .001$. When the critical flanker was on the opposite side of the screen from the hand, we found no effect of congruency on RTs, $F(1,29) = .0004$, $p = .984$. This supports previous findings that there is preferential processing of stimuli in near hand space, likely mediated by spatial attention. Further, as there was no motivation to attend to the peripheral flanker locations in order to perform the task, this suggests that the near hand space is automatically attended when there are sufficient attentional resources available.

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Attention: Features

Tuesday, May 20, 8:30 am - 12:30 pm
Poster Session, Pavilion

53.519 Learning to inhibit a salient non-target feature

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According to top-down models of attention (e.g., the contingent orienting hypothesis proposed by Folk and his colleagues), the target's diagnostic features are programmed into the attentional control settings (ACS) that then guides the system to locate the target efficiently. One consequence is that attention gets deployed, inadvertently, to an object that possesses some of, but not all, the target's diagnostic features. When search is effortful, attentional capture by non-targets compromises search efficiency. The question addressed here is the role of inhibition or suppression in attentional processing. Consider the case in which the search array contains a salient distractor, capable of competing, with the target, for attention. Would the ACS also be programmed to inhibit or suppress orienting to objects that possess the distractor's salient features? Our method combined the irrelevant singleton cueing paradigm (e.g., Folk, Remington, & Johnston, 1992, JEP:HPP, 18, 1030) with a variation of the irrelevant singleton paradigm (e.g., Theeuwes, 1992, P&P, 51, 599). The display, initially, contained several identical placeholders that were later transformed into search letters. An irrelevant singleton cue was presented prior to the appearance of the search letters. Orienting to the irrelevant singleton was measured by comparing trials in which the target appeared subsequently in the singleton's location (a valid trial) to trials in which that location was occupied later by a distractor (an invalid trial). The main manipulation was the target's saliency relative to one critical distractor. (The other distractors were homogeneous.) The focus was the condition in which the irrelevant singleton possessed the critical distractor's salient feature. Whether the irrelevant singleton succeeded in capturing attention would provide clues regarding the top-down attentional settings. Our results showed the following: (a) suppression occurred only when the target was non-salient; (b) orienting toward the irrelevant singleton occurred initially, with suppression occurring only in the later blocks.

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53.520 High-contrast distractors disrupt contrast, but not orientation discrimination

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Goal. Contrast-discrimination thresholds are much higher in the presence of high-contrast distractors, consistent with a max-pooling model of sensory selection (Pestilli et al., 2011). We investigated whether this is a general property of sensory selection. Methods. Observers viewed peripheral gratings, restricted to circular apertures left and right of fixation (6° eccentricity, 5° diameter). Stimuli were presented simultaneously in both apertures, in two intervals (600 ms stimulus intervals, 200 ms ISI). In the contrast-discrimination experiment, observers judged whether target contrast was higher in the first or second interval, while the distractor contrast was unchanged across interval. In the orientation-discrimination experiment, observers judged whether target orientation changed clockwise or counterclockwise, while the distractor orientation was unchanged across interval.

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A post-cue (400 ms after the second interval) indicated target location. In both experiments, target and distractor pedestal contrasts were systematically varied (all pairings of 10, 20, 40 and 80% contrast, excluding from the contrast-discrimination experiment conditions with identical target and distractor contrasts). Conditions were presented in randomly shuffled order, and target and distractor pedestal orientations were randomly varied across locations and trials. Results. Contrast-discrimination thresholds were much higher in the presence of high-contrast distractors e.g., relative to the effects of lower contrast distractors, 80% contrast distractors overwhelmingly disrupted performance for 10, 20 and 40% contrast targets. For orientation discrimination, however, disruption from high-contrast distractors was limited to the lowest target contrast (10%) condition, and was evident for only some observers. Conclusion. The max-pooling model posits that the largest sensory responses dominate perceptual decisions. This model can explain how sensory signals are pooled across spatial locations for 2IFC contrast discrimination, but not for an orientation-discrimination task with identical stimuli. This might reflect fundamental differences between encoding and/or visual short-term memory (across ISI in a 2IFC task) for contrast and orientation. Pestilli et al., Neuron, 72: 832-846, 2011.

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53.521 **Feature-specific predictions increase contrast sensitivity**

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The awareness of the presence of a visual stimulus on a blank background is primarily determined by the stimulus's physical contrast energy. However, the visual system's sensitivity to stimulus contrast can be modulated by the state of the observer. For example, spatial attention increases contrast sensitivity for stimuli appearing at the cued location. Here, we demonstrate that prior information about the orientation of a stimulus increases contrast sensitivity in simple detection tasks, for which orientation itself was irrelevant. In a first series of experiments, participants performed a spatial 4-AFC task, indicating the location of a Gabor patch that was sandwich masked by visual noise. Providing valid information about the orientation of the Gabor patch (e.g. "vertical") before stimulus presentation improved localization performance relative to a non-informative baseline condition and to a condition with invalid prior information. In a second series of experiments, we measured contrast detection thresholds for Gabor patches with no external noise added. Valid prior information about the orientation of the Gabors was associated with lower contrast detection thresholds. These findings indicate that prior information about specific stimulus features can dynamically enhance the effective signal of visual input matching the expected feature. Thus, feature-specific predictions do not only influence our ability to make feature discriminations, as shown previously, but also influence whether we consciously perceive a stimulus at all.

53.522 **Evidence of a feature-based attentional template in early visual areas during the absence of visual stimulation**

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Attention to behaviorally relevant features has been shown to improve visual detection in psychophysical tasks and to alter feature-selective responses in the visual cortex. According to models of feature-based attention, attending to a particular feature leads to a multiplicative gain enhancement, centered about the attended feature value (Boynton, 2009; Maunsell & Treue, 2006; Treue & Martinez Trujillo, 1999). Here, we evaluated whether feature-based attention might modulate activity in early visual areas in the absence of visual stimulation with cue-induced expectation. Observers were asked to detect a low-contrast grating, which was briefly presented on 50% of all trials. Prior to each trial, a color change occurred at fixation, indicating the likely orientation of the upcoming target (45 or 135 deg) with 80% validity for target present trials. (The color-orientation assignment was reversed halfway through the scanning session to avoid low-level confounds associated with the color cue.) Multivoxel pattern analysis was used to predict the attended and presented orientation on valid target-present trials, and demonstrated above-chance classification accuracy in early visual areas V1 through V3 (~70% accuracy). Moreover, analyses revealed successful decoding of the anticipated orientation on target-absent trials (~65% accuracy), indicating reliable bias effects in the absence of a stimulus. Critically, training on valid target-present trials led to successful generalization and classification on target-absent trials (~60%), implying that the attentional expectation of a particular orientation led to orientation-specific biases in early visual areas. Our results contribute to current feature-gain models of attention, by showing that top-down biasing of orientation-selective responses can result from a feature-based attentional template when there is no relevant stimulus to attend.

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53.523 **Target Localization Responses Diagnose Emergent Features in Singleton Pop Out**

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Subjects viewed displays containing many line segments that were identical in length and orientation except for one line, and their task was to indicate where they saw a difference by placing a mark on the display. Ss' localization responses tended to center on the one disparate line when the lines were scattered randomly across the display. When the lines were spaced so as to group into pairs by proximity, however, their responses tended toward the geometric center of the whole pair rather than to the midpoint of the one oddly oriented line (the singleton). This result is in keeping with the Theory of Basic Gestalts, which holds that singleton popout occurs not because the target is unique but because it breaks a symmetry or other emergent feature in the display, in this case parallelism. The result complements a configural superiority effect (CSE) found with oriented line segments, wherein the parallelism existing between two lines can be detected faster and more accurately than can the orientation of either line alone. Combining that CSE with the present result, we suggest that parallelism is more likely than orientation to be a basic feature in vision, and that orientation singletons pop out not because they are unique but because they break that emergent feature of parallelism. Pop out does occur in all these displays, but the thing that pops out in displays where items do not group into pairs is the literal singleton of one differently oriented line, whereas what pops out in displays that group into pairs is the whole pair that is non-parallel, in contrast to the other pairs, all of which are parallel.

53.524 **Suppressive effects of feature-based attention to motion and orientation**

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Attending to a feature enhances visual processing of that feature, but it is less clear what occurs to other unattended features. Single-unit recording studies in MT have shown a monotonic relationship between neuronal activity and the offset between the attended and neuron's preferred direction. Such a relationship should predict a monotonic suppressive effect in psychophysical performance. However, past research on suppressive effects of feature-based attention has remained inconclusive. We investigated the suppressive effect for motion direction and orientation in two experiments. In the motion experiment, participants discriminated a low coherence random dot motion (RDM) stimulus and a 0% coherent RDM stimulus. In cued trials, a cue appeared prior to the stimuli to indicate the likely direction of the signal, while in neutral trials, no cue appeared. Participants reported which interval contained the coherent motion signal. Critically, the cue was only partially valid, and on invalid trials the offset between the cued and signal direction was systematically manipulated. The orientation experiment used a similar design, with participants discriminating between a low-contrast grating embedded in noise and noise alone. A partially valid cue indicated the likely orientation of the signal grating. We measured discrimination accuracy as a function of the offset between the cued feature and signal feature. Consistent with previous research, performance was higher on valid than neutral trials. Importantly, we found lower performance for invalid trials compared to neutral trials, indicating a suppressive effect for unattended features. Interestingly, the profile of suppression for direction showed a 'rebound effect' such that maximal suppression occurred for offset ~90° but declined for larger offsets near 180°. However, the profile of suppression for orientation exhibited a monotonic function without the rebound. These results demonstrate that unattended features are suppressed during feature-based attention, but the exact tuning function depends on the specific feature.

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53.525 **Rapid feature-selection benefits from feature redundancy**

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Feature-based attention is a critical skill for exploring both real-world and artificial displays. We can select items based on a single feature dimension, such as color, shape, orientation, or motion. Here we tested whether selection performance is higher for simultaneous selection of multiple dimensions (color and shape) that specify the same set, relative to selection of either dimension alone. That is, is conjunctive selection helpful, even when

Tuesday AM

the extra dimension is redundant? We constructed a novel paradigm requiring parallel visual selection on a large set of objects. Targets formed a partial ring embedded among distractor objects. Participants were asked to indicate the quadrant of the screen where the target object ring was missing some elements. After previewing target and distractor objects, the display was rapidly flashed. Display time (M=88ms, SD=33ms) was staircased to halfway between ceiling and chance (25%) performance. Target objects (e.g., blue circles) were identical to each other, and differed from distractors in color only (color trials), shape only (shape trials), or in both color and shape dimensions (conjunction trials). Experiments 1-3 replicated the findings across three target color-shape combinations: blue asterisk, red triangle, and blue circle. Across all three, conjunctive (but redundant) feature-selection showed a massive benefit, an average of 88% performance across experiments, compared to 66% for color alone and 58% for shape alone. Selection of multiple dimensions appears to increase the likelihood of successful selection for that set, suggesting that both feature values can be selected in parallel, and combined. This finding has implications for the way that we encode features in data visualization (e.g., when graphing software such as Microsoft Excel defaults to redundant shape/color conjunctions in graph glyphs).

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53.526 Adaptation specific to conjunctions of features

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In order for us to perceive unitary objects, our visual system needs to bind object features, such as color, shape and orientation. While the areas that respond to different visual features have been well characterized, the areas that contribute to feature binding remain unclear. In the current study, we used fMRI adaptation to investigate areas that would show reductions of activation when conjunctions repeat over several consecutive displays. We compared trials in which conjunctions were repeated to trials in which the conjunctions changed, even though the features remained the same. Adaptation effects were found in the left and right parietal cortex and a similar trend was observed in the lateral occipital complex (LOC). Our results provide evidence for the role of the parietal cortex in binding and in object representation using a paradigm that removes difficulty and spatial scanning confounds that have influenced many previous studies of the neural correlates of binding.

53.527 Can Attention be Guided Efficiently by a Negative Template?

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Attention can be allocated to relevant objects based on a particular feature value or location. Recent work suggests a cued feature can also be used to direct attention away from irrelevant objects. Using a twelve-item circular search array (two colors), Arita et al. (2012) found a negative cue (distractor color) facilitated search relative to a neutral cue (color not present), but was not as efficient as a positive cue (target color). This suggests observers used the negative cue to bias search away from known irrelevant objects. Object color and hemifield position, however, were correlated – left hemifield contained items of one color, right hemifield contained items of another color. Observers could have used this correlation to convert negative cue feature into relevant location. It would be advantageous to identify which hemifield contained the cued irrelevant color, then shift attention to the opposite. If object color and hemifield position were not correlated, search in the negative cue condition might not be as efficient. We used the same search task as Arita et al. (2012), but made two changes: search arrays were segregated (left hemifield contained six red objects, right hemifield contained six blue objects) or mixed (each hemifield contained three red and three blue objects), and the cue indicated the relevant feature (red) or location (left arrow). When observers were presented with a negative location cue (irrelevant hemifield), response times were as fast as with a positive location cue (relevant hemifield). However, when observers were presented with a negative color cue, response times were as slow as with a neutral cue, even when the colors were segregated by hemifield. These results suggest that, when object color and location are not correlated, observers cannot easily use color information to employ a "template for rejection" and bias search away from known irrelevant objects.

53.528 Feature-based attention and trans-saccadic correspondence

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Trans-saccadic correspondence is the process by which pre-saccadic, peripheral visual targets and post-saccadic, near-foveal visual targets are matched. One hypothesis suggests that each saccade toward a target is followed, once the saccade lands, by a search for the best match, typically the target closest to the landing position. This process, the landmark effect, recalibrates the spatial coordinate frame and so supports visual constancy (Deubel et al., 1996, 1998). In this study, we investigated whether this post-saccadic search is related to classic feature-based visual search. Specifically, we measured whether the features of the saccade target speeded a subsequent visual search for the same target. Participants maintained central fixation during the presentation of a peripheral target, and then performed a visual search task. In the saccade condition, the target disappeared and a visual search array appeared around the landing position. In the fixation condition, the peripheral target disappeared while the visual search array appeared around the fixation point. The visual search target could either be congruent or incongruent with the peripheral target. Preliminary results show no benefit of congruency between peripheral and visual search targets in either condition. This suggests that the search for the saccade target on landing does not call on processes in common with standard feature-based visual search. On the contrary, we found that reaction time in a conjunction search (but not in a disjunction search) may be slower when a saccade is performed, suggesting that a preceding saccade impedes visual search.

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53.529 Where Do People Look at in Crowded Natural Scenes?

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Human visual attention is directed to look at salient stimuli in the environment. Previous models to predict saliency in natural images usually focused on regular-density scenes. What drives attention in a crowd, however, could be significantly different from the conclusions from the regular setting, and it remains unclear how the crowd density of a scene influences the selection of attention in the context of natural complex scenes. To study saliency in crowd, we first constructed a database. We collected a set of 500 natural images with a diverse range of densities, and conducted eye tracking experiments where 16 subjects free-viewed the 500 images (5s per image). Faces have been shown to attract attention strongly and rapidly, independent of tasks, therefore we focused our studies here on human faces, and the selected images with a large range of face densities (i.e., 3~268). Our dataset also provided labels of face regions as well as their attributes including pose and partial occlusion. We investigated the influence of crowd density on a number of variables including low-level features and face related features (e.g., size, local density, pose, and occlusion). Statistical analyses showed that faces attract attention strongly across all crowd levels, yet the importance of faces in saliency decreased as crowd level increased. We also observed that the number of fixations did not change significantly with crowd density, suggesting that only a subset of faces attract attention in crowd. What then are the driving factors to determine which faces (or non-face regions) to look at? Analyses showed that larger faces and faces with smaller local density (i.e., less surrounding faces) attracted attention more strongly. Furthermore, frontal faces and unoccluded ones were found to be more salient. Finally, despite the general conclusions, evidence was found that crowd density modulated the correlation between saliency and features.

53.530 Individual Differences In Obligatory Processing of Unexpected, Intentionally-Ignored Events

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The natural environment's predictable structure facilitates various cognitive tasks, from planning motor behaviors to efficiently allocating attention. We set out to study the cognitive and neural impact of unexpected items that subjects are attempting to ignore. To do this, we adapted Eriksen's flanker task to incorporate "standard" and "oddball" distractors. Arrays of five chevrons were briefly presented (50 ms), and subjects reported the orientation of the central target chevron, attempting to ignore the four chevrons that flanked the target. We manipulated the orientation of the distractors, creating standard (90% of trials) and oddball (10%) orientations. Congruent and incongruent configurations, and left- and right-pointing central targets were equiprobable. While subjects performed the task, we recorded scalp EEG signals. EEG measures included the visual mismatch negativity (vMMN) elicited by oddball flanker directions, and alpha-band (8-12 Hz) oscillations preceding stimulus onset. Subjects also completed the Adult Temperament Questionnaire, a measure of sensory, emotional, and motor reactivity and control. Behaviorally, oddball flankers substantially enhanced the flanker congruency effect: subjects responded fastest and most accurately on trials with oddball flankers that were congruent with the central target, and slowest and least accurately on trials with oddball flankers that were incongruent. Oddball flankers also elicited a vMMN. Importantly, individual differences in vMMN magnitude were predicted

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by two factors of temperament: orienting sensitivity and attentional control. Subjects may be using the predictability of the flankers to facilitate intentional ignoring, a strategy that breaks down when confronted with oddballs. Unexpected events are obligatorily processed, even when they occur among distractors. Such events leak through subjects' intentional ignoring, influencing neural responses and behavioral performance.

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53.531 **Interference from an integral feature in visual statistical summary representations** Jesse Moyer[1](jmoyer@psych.udel.edu), Timothy Vickery[1]; [1]Department of Psychology, University of Delaware

Humans are capable of computing an accurate representation of the average value of a given feature within a set, including size (Ariely, 2001), brightness (Bauer, 2009), or orientation (Dakin & Watt, 2009). In the natural world, members of a set may vary across many feature dimensions. Can we selectively attend to a single feature and ignore other features when computing a summary statistic? Prior research (Moyer, Payne, Pitts, & Palomares, VSS 2012) demonstrated that estimations of average length or orientation are unaffected by the presence of variability in the other feature dimension. However, length and orientation are separable features; are feature averages similarly immune to variability of an irrelevant but integral feature? In the current study, we examined whether estimation of average height is influenced by irrelevant variability in width, given that height and width are known to be integral features. On each trial participants were briefly presented with sets of rectangles and judged average height, or sets of lines and judged average line length, using an adjustment procedure. An irrelevant integral or separable feature (rectangle width or line orientation, respectively) was either homogenous (all items were the same width or orientation) or heterogenous (widths or orientations were randomly varied). Consistent with prior work, we found no accuracy cost for computing the average of length while orientation was varied. However, participants were less accurate at judging average height when width was varied than when it was held constant. Our results suggest that statistical summary representations are not immune to variance in non-target feature dimensions if the two dimensions are integral, yet summary representations remain robust to variance in separable feature dimensions.

53.532 **Parallel vs. sample-based extraction of summary statistics from feature and conjunctive sets** Mariia Bulatova[1](bulatovamaria@yandex.ru), Igor Utochkin[1]; [1]National Research University Higher School of Economics

The visual system efficiently extracts summary statistics (the average or approximate numerosity) from multiple objects at a brief glance instead of encoding individual features (Alvarez & Oliva, 2008; Ariely, 2001). Treisman (2006) claimed that this statistical processing involves globally distributed attention. Following her Feature Integration Theory, Treisman predicts that summary statistics can be derived from feature-marked sets as they are driven by early feature maps, but it is not the case for conjunction-marked sets requiring focused and severely limited attention for feature binding. Treisman confirmed this prediction in a proportion estimation experiment. Previously, we replicated that experiment with subsequent modifications (Bulatova & Utochkin, 2013) and found that observers can be as good at estimating the proportions of conjunctions as at estimating feature proportion, when the number of concurrently presented subsets is controlled properly and not exceeding the limits of working memory capacity. In our current experiment, we tested the mechanisms of this statistical representation. Observers were presented with sets of red, green, or blue T's, X's, and O's and had to evaluate the percent of a precued or postcued feature (either color, or shape) or their conjunction. The spatial distribution of relevant items could be either even over the field, or uneven. We found that spatial distribution only slightly affected the accuracy of feature estimation supporting the notion of massively parallel statistical processing. However, uneven distribution substantially impaired the accuracy of proportion estimation for conjunctive sets. It indicates the failure of parallel processing of such sets. It appears that observers focused their attention on few sample items within a limited region and approximated their estimate to the entire visual field (Myszek & Simons, 2008) which is a good strategy for even but not uneven distributions. Overall, our conclusions are consistent with the Treisman's (2006) account.

Acknowledgement: HSE Basic Research Center

53.533 **Ensemble Processing of Color and Shape: Beyond Mean Judgments** Danielle Albers[1](dalbers@cs.wisc.edu), Michael Correll[1], Michael Gleicher[1], Steven Franconeri[2]; [1]Department of Computer Sciences, College of Letters and Sciences, University of Wisconsin-Madison, [2]Department of Psychology, Weinberg College of Arts and Sciences, Northwestern University

When faced with a large collection of objects, our visual system can extract statistical properties of the collection. Most studies of this ability focus on judgments of mean value, and typically focus on a constrained set of dimensions (e.g., size, location, or facial properties). We tested a variety of judgments in addition to means - deviation, range, and extrema – across two dimensions that have real-world application to encodings of visual information – color (as in the color gradients used in heatmaps) and line height (as used in line graphs). People were asked to find the window within a range (with a cover story of months within a year of data on daily sales for a company) that had the largest mean, deviation, etc. We found that while the visual system can effectively extract statistics from both dimensions, there was a salient double dissociation between the two. For ensemble processing of color gradients, performance was best for statistics requiring the combination of information across values, such as recovering mean and deviation. In contrast, for ensemble processing of line height, performance was best for statistics requiring isolation of unique elements across values, such as recovering extrema and range. We replicated these results using modified versions of each representation in typical data analysis tasks: a line graph that included explicit information about judged properties and a color gradient that was randomized within 'months' to facilitate ensemble processing of each month. Overall, these findings suggest divisions in the type of ensemble processing that is possible for different types of stimuli. We speculate that color facilitates mean and variability information via summation of values at low spatial frequencies into a representation similar to a color histogram, while line height facilitates range and extrema judgments via existing biases toward shape boundary properties

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Attention: Objects

Tuesday, May 20, 8:30 am - 12:30 pm
Poster Session, Pavilion

53.534 **Amodal completion without awareness** San-Yuan Lin[1](lin.sanyuan@gmail.com), Su-Ling Yeh[1,2,3]; [1]Department of Psychology, National Taiwan University, Taipei, Taiwan, [2]Graduate Institute of Brain and Mind Sciences, National Taiwan University, Taipei, Taiwan, [3]Neurobiology and Cognitive Neuroscience Center National Taiwan University, Taipei, Taiwan

The extent of unconscious processing is under extensive investigation. Yet, it remains unknown whether amodal completion—a fundamental process that completes spatially discontinuous objects by illusory contours and surfaces—also occurs without awareness. We examined this by adopting the double-rectangle cueing paradigm (Egly, Driver, & Rafal, 1994) with a temporal-order judgment (TOJ) task. Specifically, an occluder and four squares (served as the parts of the two to-be-completed rectangles) were presented in separate eyes in a continuous flash suppression paradigm so that the stimulus in one eye is suppressed from consciousness. The cue and the subsequently presented two concurrent targets for the TOJ task were shown within the four squares. If amodal completion did occur to form two rectangles from the four squares and the occluder, the proportion of prior entry for the two targets would differ in the TOJ task. Furthermore, to ensure unconscious processing, trials with reports of seeing the suppressed stimuli were excluded. In Experiment 1, a reversed same-object advantage—target on the uncued rectangle was judged to appear earlier more often than target on the cued rectangle—was found in such arrangement. This is also true when the stimuli swapped—the occluder became visible and the squares invisible (Experiment 2). The reversed same-object advantage suggests that amodal completion occurs but may be weak to constrain object-based attention to prioritize within-object information in the tug-of-war of "within-object or between-object selection" when the display is only partly seen. To test this, in Experiment 3, we increased the strength of the object representation by inducing amodal completion at conscious level and found the same-object advantage. These results altogether suggest that amodal completion occurs unconsciously and that the depth of unconscious processing can be extended beyond contours and surfaces that are spatially continuous.

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53.535 No masked priming of shape in metacontrast and object substitution masking paradigms without attention

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Masked priming effects are taken as evidence that behavior can be influenced by information that does not reach our phenomenal awareness and hence serves as a dissociation between perception and awareness. Priming with unseen stimuli in studies using metacontrast masking procedure are well established, while priming in object-substitution masking (OSM), an alternate masking paradigm, are less well established. Metacontrast and OSM paradigms both significantly reduce visibility of stimuli. However, the former suppresses stimuli even under conditions of focused attention while the latter requires stimulus location uncertainty and distributed attention for masking to occur. Given that attention modulates masked priming effects, we predicted that masked priming should be more robust in metacontrast than OSM paradigms, and that priming in metacontrast should be reduced in distributed attention conditions. Consistent with previous studies we found significant priming with detected primes in both metacontrast and OSM paradigms. Under traditional focused attention conditions (when prime and probe were the only stimuli in the display) we obtained priming with undetected stimuli in a metacontrast paradigm. However, under conditions of distributed attention (when additional task-irrelevant lures were presented in the display) priming with undetected stimuli disappeared. Further, we found no evidence of priming with undetected stimuli in OSM, where distributed attention is required for suppression of stimulus visibility in the first place. Together, these results indicate that nonconscious priming of shape requires some degree of focused attention.

Acknowledgement: NIH R01EY022605

53.536 The acquisition of attentional templates for target objects in visual search

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Representations of current target objects (attentional templates) guide attentional selection in visual search. To find out how such templates are acquired during object learning, we employed a cueing procedure. A word cue (e.g., "trousers") informed participants about the target object for a series of visual search displays. Each cue was followed by four search displays with line drawings of real-life objects. The target object appeared together with three different distractor objects, and participants had to respond to the location of the target (upper or lower visual field). To track attentional object selection in real time, we measured the N2pc component of the event-related brain potential. RTs were much slower to targets that immediately followed the word cue relative to the next three targets. N2pc components to the first target were also attenuated and delayed relative to the N2pc to the three subsequent targets. In contrast, there were no RT and N2pc differences between the second, third, and fourth target object in a run. These findings show that in general symbolic word cues are insufficient to guide attentional object selection efficiently. To fully establish attentional object templates, visual features of target objects need to be encountered at least once. However, additional analyses based on RT median splits revealed that for a subset of the target objects used, an early and large N2pc was already triggered on their first presentation. For these "highly imagible" objects, efficient attentional templates can be elicited by abstract cues.

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53.537 Effect of object-substitution masking on the perceptual quality of object representations

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The near exclusive use of forced choice tasks in object-substitution masking (OSM) paradigms has restricted their use to identifying coarse changes in target processing. To resolve this limitation the present study combines OSM paradigms with a delayed report paradigm from the working memory literature (Wilken & Ma, 2004; Zhang & Luck, 2007). This paradigm relies on a mixture model approach that allows for an estimate of the separable contributions of two components to task performance—one component being the precision of target representation, and the second being a guessing component. Participants estimated the gap location (0 to 360 degrees) of oriented Landolts identified by a four dot mask. In Experiment 1, using a standard OSM paradigm, both set size (2, 4, 8) and mask duration (0, 150, 300 ms) were varied in order to investigate their effects on estimates of the precision and guessing components. Estimates of guessing increased as a function of increases in both set size and mask duration. In contrast, estimates of precision were reduced only for increases in mask duration. In Experiment 2, we controlled for mask energy using a novel OSM paradigm described by Jannati, Spalek and Di Lollo (2013). This paradigm manipulates the interstimulus interval (ISI) between the initial display (both target and mask presented) and a following mask only display. Using this paradigm, effective masking has been shown for ISIs of less than 80 ms but not for larger ISIs. Results using this novel OSM paradigm converged with those from the standard OSM paradigm in showing that masking decreases precision and increases guessing. Using this mixture model approach which provides the ability to obtain a richer measure of object representation we found that OSM can produce not just perceptual effacement but also perceptual degradation of a target's representation.

Acknowledgement: NSERC

53.538 Familiarity wins over novelty: A persistent attentional bias toward regularities

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The visual environment is often stable, but some aspects may change over time. For example, the furniture in the room may be re-arranged, and new furniture may replace old ones. The challenge for the mind is thus to update knowledge about the environment in light of new information. Here we examine whether the attentional bias to regularities can be shifted in the presence of new stimuli. The experiment consists of two halves. In the first half, observers viewed four simultaneous streams of shapes. The stream in one 'structured' location contained triplets, the shapes in one 'random' location were randomized, and a gray square appeared in each of the two 'neutral' locations. Occasional search arrays were presented where the target appeared randomly at one of the four locations. In the second half, everything was the same except that the stream in the structured or the random location may change. Several changes occurred across four conditions: (1) the structured stream became random; (2) the random stream became structured; (3) the random stream now contained new random shapes; and (4) the random stream now contained new structured shapes. In the baseline condition, no change ever occurred. We found that in all conditions, during the first half of the experiment, target discrimination was reliably faster for targets at structured vs. random or neutral locations, suggesting that attention was drawn to the structured location. In the second half, regardless of condition, target discrimination was again reliably faster for targets at structured vs. random or neutral locations. This suggests that attention persisted at the previously structured location, even though the stream was no longer structured, or newly structured stream or new shapes emerged in another location. These findings reveal the robustness and persistence of the attentional bias to regularities even in the presence of novel stimuli.

53.539 Object-Based Attention is Modulated by Shifts Across the Meridians

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Object-based attention yields a performance advantage for targets on the same object compared to targets on different objects. Although most published reports find evidence of a same-object advantage (SA), certain situations evoke a same-object cost (Davis & Holmes, 2005). Pilz et al. (2012) reported that most individuals do not show SA, and SA is more prevalent for rectangular objects oriented horizontally than vertically; consistent with attention being more efficiently allocated along the horizontal meridian. To explore these object-based effects when explicitly controlling for shifts of attention across either the horizontal or vertical meridian, we reanalyzed published data from four experiments (Pilz et al., 2012; Greenberg, 2009). In each experiment, rectangle orientation (horizontal vs. vertical) was a factor, allowing computation of SA while controlling for attention shift direction. We controlled for shifts across meridians by subtracting the different-object RTs for one object orientation from the same-object RTs for the other object orientation, thus ensuring that subjects' attention focus never crossed a specific meridian. Results showed that (1) controlling for meridian shifts failed to produce a same-object cost at the group level, (2) shifts within one side of the vertical meridian produced larger SA than for the horizontal meridian, and (3) a smaller proportion of individual subjects showed same-object costs when controlling for meridian shifts. Furthermore, when the target was part of the object (cf. Watson & Kramer, 1999), there was no difference in SA between our meridian analyses, unlike when the target was placed on the object. We conclude that controlling for attention

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shifts across meridians provides an important perspective on SA. Object-based effects are stronger when attention shifts are confined to one side of the vertical meridian (vs. horizontal). Examining orientation differences confounds meridian shifts (and therefore brain hemisphere representations), which may explain inconsistent SA observations in the literature.

53.540 Reduced attentional competition between objects that follow real-world regularities

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In virtually every real-life situation humans are confronted with complex and cluttered visual environments that contain large amounts of visual information. Because of the limited capacity of the visual system, not all of this information can be processed at a given time. Consequently, items within a scene are competing for attentional resources. But what is the "unit" of this attentional competition? What counts as an item? Here, using fMRI and behavioral measures, we report reduced attentional competition between objects positioned according to commonly experienced configurations, such as a lamp above a table. In an fMRI study designed to measure competitive interactions between objects in visual cortex (Kastner et al., 1998), we found reduced neural competition between objects that were shown in regular configurations. Using a visual search task we then related this reduced competition to improved target detection when distracters were presented in regular configurations. These results indicate that attentional competition is reduced for objects shown in familiar configurations. We interpret the current findings as reflecting the grouping of objects based on higher-level spatial-relational knowledge acquired through a lifetime of seeing objects in specific configurations. This grouping effectively reduces the number of objects that compete for representation. Because scenes contain a large number of objects that occur in regularly positioned groups of two or more objects, such grouping might operate on many objects in a scene to greatly enhance the efficiency of real-world perception.

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53.541 Scene-based information does not disrupt visual object correspondence

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Visual objects are usually embedded within meaningful scenes. Previous work has shown that scene-based information can support perceptual object correspondence by providing causal explanations for abrupt changes in objects' features (e.g., Moore, Mordkoff, & Enns, 2007). The present study examines whether scene-based information can disrupt object correspondence by inducing conflict between scene-based information and object feature information. To this end, we employed the object-reviewing paradigm and manipulated the perceived illumination of the scene with the help of the checkershadow display (Adelson, 1995). Participants identified whether a probe on the object was same or different after the object had translated across the checkerboard through the shadow. In line with previous findings (e.g., Moore, Stephens, & Hein, 2010), we observed an object-specific preview benefit even when the object's surface luminance changed under the shadow to be consistent with the scene. In a critical condition, objects moved between differently illuminated areas on the checkerboard but without changing their luminance accordingly. Consequently, information provided at the object-feature level signaled object correspondence whereas information provided by the scene indicated an abrupt change in object lightness, which in turn should violate the perception of object correspondence. The abrupt change in perceived object lightness did not reduce the object-specific preview benefit. This suggests that consistent object-feature level information can overcome disruptive scene-level information for the maintenance of object correspondence.

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53.542 Exploring the Relationship between Object-Based Attention Effects and Object Realism

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Attention can be allocated to locations in space, but evidence also suggests that the allocation of attention can be shaped by the presence of objects (object-based attention). Recently the prevalence of object-based attention effects has been questioned, supported by evidence from a series of large sample size experiments (Pilz et al., 2012; PLoS). We conducted a study (N = 120) to further explore the factors that determine when and if object-based effects are observed, focusing on the degree to which the concreteness and realism of objects in the display contribute to object-based effects. Rather than abstract bars or unfamiliar wrench-like objects, the objects that were cued were extremely familiar: items of silverware. Fully realistic or cartoon images of silverware were cued and the target could appear either at the cued location, on the same piece of cued silverware, or on a different piece of silverware. We also tested object-based effects using standard abstract bar stimuli. Predictions were driven by the idea that the visual system evolved to process complex, familiar, and real-world objects. Contrary to predictions, the realism and concreteness of objects did not modulate object-based effects. Instead, object orientation appeared to have the largest effect, with object-based effects largely being observed when objects were arranged horizontally on screen compared to vertically. Overall, results support that horizontal attention shifts in general are facilitated and provide little evidence for object-based attention effects.

53.543 Target Identity Uncertainty and the Stages of Object-Based Attention: A Prioritization Account

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Attention is allocated preferentially according to object boundaries; regions of an attended object enjoy an attentional benefit over non-attended objects. Two theoretical mechanisms have been proposed to account for object-based attentional benefit: (1) Attentional Spreading hypothesis, proposing spreading of attention within an attended object; and (2) Attentional Prioritization hypothesis, suggesting that this advantage stems from increased prioritization given to locations within an already attended object, and that this prioritization is mediated by certainty about the visual scene. Some evidence favoring attentional prioritization has been observed with a flanker paradigm using a cross-like display measuring the degree of interference exerted by flanking letters as a function of whether flankers appear on the same- or different-object (Shomstein and Yantis, 2002). Recent evidence, using a data-limited (accuracy around 70%) cross-like display, provided further support for attentional spreading, arguing that reaction time measures may not have been sensitive to object-based flanker interference effects (Ho, 2011). Here we argue that uncertainty is the factor that drives object-based attentional selection via attentional prioritization, rather than attentional spreading, modulated by segmentation cues signaling object boundaries. We tested different levels of target-based identity uncertainty and its influences on the flanker interference effect by dividing the data-limited cross-like paradigm into three levels of uncertainty: high, accuracies of 60-80%; moderate, accuracies 70-80%; and low, accuracies 80-100%. Additionally, segmentation was manipulated by varying colors of objects with an expectation that segmentation cues should modulate flanker interference effects to a greater extent. We observed that flanker interference was modulated by object representation only under high levels of uncertainty and only when segmentation cues were available. Taken together, these findings indicate that when uncertainty regarding target identity is high, object representations influence attention, however, once uncertainty is eliminated; objects no longer constrain attentional allocation, consistent with the attentional prioritization account.

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53.544 Temporal uncertainty determines the use of object representations in attentional guidance.

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Several lines of evidence suggest that object representations contribute to attentional guidance under conditions of high spatial uncertainty (Drummond & Shomstein, 2010). Others suggest that object representations guide selection even when spatial certainty is high (Chen & Cave, 2006). Here we re-evaluate the role of uncertainty in object-based attentional guidance. In a series of experiments, we examine the extent to which temporal uncertainty influences object-based attention. Using a display consisting of three rectangles, arranged in a cross-shape, flanker interference was measured as a function of whether flankers appeared on the same or different object. In the Mixed Temporal Uncertainty experiment, uncertainty was manipulated by introducing a distribution of delays for the onset of the display with a mean of 2000ms and a standard deviation of 500ms in the uncertain condition and a constant delay of 2000ms in the certain condition. In the Varied Temporal Uncertainty experiment, uncertainty was manipulated by either introducing a distribution, with a mean of 1500ms and a standard deviation of 200ms, for the uncertain condition or a less varied distribution, with a mean of 1500ms and a standard deviation of 50ms, for the certain condition. Effect of compatibility was observed for all temporal uncertainty experiments, with incompatible flankers interfering to a greater extent than compatible flankers. Object based flanker interference was also found under conditions of temporal uncertainty, such that greater flanker interference was observed for targets and flankers that appeared on the same object as compared to when flankers appeared

on a different object. We conclude that uncertainty is a major determining factor in object-based guidance of attention, with object-based representations influencing attention selection when temporal uncertainty is high. Additionally, these results provide strong evidence that uncertainty in general, not just spatial uncertainty, predicts object-based attention.

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53.545 **Task-context dependent visual object representation in human parietal cortex** Su Keun Jeong[1](skjeong@fas.harvard.edu), Yaoda Xu[1]; [1]Department of Psychology, Harvard University

Both monkey neurophysiology and human fMRI studies have shown that in occipital-temporal cortex, neural response to multiple visual objects shown simultaneously can be reliably predicted by the averaged neural response of the component objects shown alone. Besides occipital-temporal cortex, visual object representation has also been shown in the primate parietal cortex. Does a similar representation for multiple visual objects exist in the primate parietal cortex? Using multi-voxel pattern analysis, we examined object representation in human inferior and superior intra-parietal sulcus (IPS), two parietal regions implicated in visual object individuation and identification, respectively. As a comparison, we also examined response from object shape processing region in lateral occipital (LO) cortex. During the experiment, participants saw either a pair of objects shown above and below the fixation, or a single object shown at either location. In all three regions, distinctive fMRI response patterns were found for the different single objects and object pairs shown, confirming visual object representation in these brain regions. Replicating previous findings, in LO, object pair patterns were indistinguishable from the averaged patterns of the component objects shown alone. In both inferior and superior IPS, however, object pair patterns differed significantly from those of the component objects. This pattern difference could be attributed to task context difference between attending to a single object and attending to a pair of objects. When such difference was removed by only examining paired objects, we found that the averaged pattern of two object pairs (e.g., A+B and C+D) was indistinguishable from those of two other object pairs containing the same four component objects (e.g., A+D and C+B). These results suggest that parietal response to multiple objects can be predicted from responses to the components objects, but only under the same task context. Human parietal cortex thus contains both object and task representations.

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53.546 **Do self-controlled objects "pop out"? A study of attention** Hideyuki Kobayashi[1](koabayashi.h.aa@m.titech.ac.jp), Takako Yoshida[1]; [1]Department of Mechanical Sciences and Engineering,Tokyo Tech

It has been reported that the self-controlled mouse cursor among randomly moving distractor cursors is easy to find for the operator but not for others. An application of this is called the Ninja Cursor (e.g., Watanabe et al., 2013). To test the contribution of attention to this phenomenon, we undertook a simple visual search experiment for a self-controlled object. The participants' task was to search for a target Landolt C from the randomly moving Landolt C and report the direction of the target Landolt C. Two conditions were employed: the self condition, in which participants controlled the target Landolt C position freely via a computer mouse, and the second condition, in which the participants searched for the target Landolt C that moved in accordance with the recorded mouse movement of the other individuals. Overall, results showed typical search slopes, and reaction time increased linearly alongside the number of Landolt Cs in a display. However, the self-condition showed a much shallower search slope, suggesting that participants could search for the self-controlled cursor with relatively little attentive cost, as if it were "popping out." To further test the contribution of the multimodal discrepancy and the sense of the intuitive controllability or agency to the cursor, a temporal delay was inserted between the mouse and cursor movement. As the delay increased, the search slope became steeper and the participants lost the sense that they were operating the target. The critical temporal delay that matched the performance of the delayed self-conditions to the other condition increased alongside the number of distractors. These results suggested that the visual feedback that matches the ongoing action or movement would easily summon one's attention. This attraction would play a critical role in distinguishing subject and object, or self and others, in our visual field.

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53.548 **The effect of perceptual narrowing on category-based visual search: an ERP study** Rachel Wu[1](rachelwu2006@gmail.com), Jared Band[1], Rebecca Nako[2], Gaia Scerif[3], Richard Aslin[1]; [1]Department of Brain and Cognitive Sciences and Center for Visual Science, University of Rochester, [2]Department of Psychological Sciences, Birkbeck, University of London, [3]Department of Experimental Psychology, University of Oxford

Visual search guided by attentional templates specifying target-defining features (e.g., your car keys) is more efficient than category search (e.g., any type of keys). However, some categories of objects may be processed more efficiently because individual exemplars are not discriminable due to the absence of expertise (i.e., perceptual narrowing). With adults, we measured the N2pc component (an early ERP marker of target selection) in a visual search experiment where targets were defined as either one item (i.e., a specific monkey face) or categorically (i.e., any monkey face) among distractors from a different category (i.e., other animal faces). In addition to target-matching trials, foil trials presented participants with a category-matching non-target (i.e., Face 2) while participants were asked to search for Face 1. If foil trials elicited the N2pc component, it would indicate that participants used a category-based search strategy (i.e., find any monkey face) prior to searching for a specific monkey face. The N2pc was largest during search for a single monkey face, demonstrating that target selection is most efficient when it is guided by a feature-specific template. There was a smaller N2pc on category search trials, indicating that search for any monkey face was less efficient than search for a specific monkey face. Finally, a small but reliable N2pc was present on foil trials, suggesting that participants did initially consider non-target monkey faces as targets prior to indicating target absence with a behavioral response. Our results are threefold: First, category-based search can operate at early visual stages. Second, category-matching non-targets attract attention, suggesting that category search in this case precedes identity search (i.e., locating any monkey face prior to locating a specific monkey face). Third, despite this search strategy (due to perceptual narrowing), the N2pc at the category level is still less efficient than feature-guided search.

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Visual search: Context and memory

Tuesday, May 20, 8:30 am - 12:30 pm
Poster Session, Pavilion

53.549 **A comparison of static and dynamic visual search tasks in eliciting visual working memory guidance of selective attention** Zhan Xu[1](xuzhan@swu.edu.cn), Jianhua Li[1]; [1]Key Laboratory of Cognition and Personality, Ministry of Education, School of Psychology, Southwest University, Chongqing, China

Some previous research indicated that visual attention can be automatically captured by sensory inputs that match the contents of visual working memory (Soto, Heinke, Humphreys, & Blanco, 2005). It also found that information in visual working memory can be used flexibly as a template for either selection or rejection according to task demands (Woodman & Luck, 2007) or that the visual working memory guidance of selective attention can be caused by the differences in the perceptual difficulty of the search tasks used (Han & Kim, 2009). Usually, researchers have used static search tasks in the dual-task paradigm but have manipulated other variables such as color or shape. This study employed a dynamic visual search to verify whether and how the dynamic search would affect the memory-driven attentional capture effect. Experiment 1 manipulated the stabilization of spatial configuration by using constant angular velocity uniform circular motion. The results indicated that the capture effect occurred regardless of the stabilization of the spatial configuration. Experiment 2 investigated whether the moving trajectory of items would mediate the relationship between working memory and attention by comparing two moving trajectory conditions: constant linear velocity uniform circular motion and irregular motion. The results of experiment 2 suggested that the moving trajectory couldn't affect the attentional capture effect. Experiment 3 varied the velocity of motion to investigate whether different velocities would change the capture effect. The results showed that the effect appeared in both restrictive uniform circular motion and irregular motion when the velocity was doubled. In addition, the magnified velocity did not dilute the capture effect. The findings of all three experiments

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suggested that the working memory-driven attentional capture was a robust effect even in dynamic visual search tasks. The different patterns of motion didn't change the effect and velocity did not affect the process.

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53.550 Examining the influence of nonpredictive arrow cues and a working memory load on visual search performance

Gerald McDonnell[1](gmcdonnell@huskers.unl.edu), Michael Dodd[2]; [1]University of Nebraska-Lincoln, [2]University of Nebraska-Lincoln

The purpose of the current study is to examine the interaction between a task-irrelevant working memory load and the allocation of visual attention. Previous research has demonstrated that when an item is held in working memory, attention shifts towards items that either match–or are similar in feature to—that of the working memory load (i.e., Downing, 2000). Holding nonpredictive arrow cues in working memory also results in the guidance of visual attention, where participants are faster at responding to a target when target location is congruent with arrow direction (McDonnell & Dodd, 2013). In Experiment 1, participants were first presented with a to-be-memorized circle or square for a subsequent memory test. After shape offset, participants then completed a visual search task where they responded to a singleton gap in an array of circles and squares. This was followed by a forced-choice memory test to ensure the shape was maintained in working memory. Surprisingly, slower reaction times were observed in the unrelated visual search task when the target shape matched the memory load shape relative to when the target and memory load shape did not match. When the working memory load consisted of a nonpredictive arrow cue (Experiment 2), or when a nonpredictive arrow cue appeared in the display while a shape was held in memory (Experiment 3), participants were always faster responding to the target at directionally cued locations. Experiment 4 examined whether the counterintuitive results in Experiment 1 were attributable to participants avoiding display shapes that may interfere with the working memory load via eyetracking. The present experiments provide an important dissociation regarding interference and facilitation in working memory, in addition to providing insight into the relative strength of attentional cues.

53.551 Changing how you search alters the influence of memory on attentional allocation and eye movements

Jordan Grubaugh[1](jordangrubaugh23@gmail.com), Mark Mills[1], Brett Bahle[1], Edwin Dalmaijer[2], Stefan Van der Stigchel[2], Michael Dodd[1]; [1]Cognitive Psychology, University of Nebraska-Lincoln, [2]Experimental Psychology, Utrecht University

Previous research has found that inhibition-of-return (IOR) is a task-specific strategy, where participants are significantly slower to return to previously fixated locations in a search task compared to in a non-search task, where facilitation-of-return (FOR) is observed (Dodd et al., 2009). In these contexts, IOR and FOR reflect a differential influence of memory on attention as a function of task demands. Moreover, task set influences the spatial and temporal characteristics of eye movements, such as the rate of change in fixation duration (Mills et al., 2011). In these tasks, search is generally participant-directed, meaning participants have no expectation regarding where the target will appear and can search however they choose. Many real world search tasks, however, are constrained by top-down knowledge regarding a target's expected location, which can be replicated in the laboratory via experimenter-directed search (participants receive explicit direction where to search).. The purpose of the current study was to examine the influence of task set (search, memorize, evaluate) and search type (experimenter-directed vs. participant-directed) on oculomotor behavior. Participants were presented with a series of scenes that pictured common real-world environments (e.g., kitchens) and either a) searched for an embedded N or Z, b) memorized the scene, or c) rated the pleasantness of the scene. Task type could be blocked or mixed and participants were either provided with specific direction as to where targets were likely to appear or were told the target could appear anywhere. Critically, whereas participant-directed search yielded IOR, experimenter-directed search yielded FOR in both mixed and blocked conditions. The rate of change and magnitude of fixation durations was also impacted by search instruction. These results demonstrate an important dissociation between the facilitatory and inhibitory effects of memory on attention and eye movements as a function of search type.

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53.552 The role of working memory capacity in visual search and search of visual short term memory

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We can perform goal-directed search for currently visible objects (visual search) and for objects recently seen ("Was that an eagle?" Visual short term memory (VSTM) search). Observers working memory capacity (WMC) might influence either. In visual search, it could modulate selection by influencing the target template, held in memory. In VSTM search, it could influence the quality of the memory for the stimuli. Observers searched for a specific target among 6 items. Of these, 2 - 4 were from the target category (bird or cake). The other 2 - 4 were from the other category. In visual search, category was precued for 200 msec. After an 800 – 1300 msec delay, the specific target image was shown (200 msec). After another 800 – 1300 msec delay, the search display was shown (200 msec). In VSTM search, the cues were shown after the search display. Thirteen observers had their WMC assessed using measures adapted from different authors (e.g., Luck and Vogel, 1997). Visual search was much easier than VSTM search (d': 3.11 vs .76). High WMC observers performed better than low (d': 2.20 vs. 1.78; $t(11) = 2.496$, $p < .05$). Performance interacted with WMC and the number of items in the target category (setsize). Setsize had a bigger effect on VSTM search performance for low WMC. Curiously, setsize had a bigger effect on visual search performance for high WMC, though low WMC remained worse overall. The results suggest that these two searches may not share the same underlying processes.

53.553 Categorical Contextual Cueing in Visual Search

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When looking for things in our daily environments, we often rely critically on the contextual associations between objects, learned through prior experience. For example, when searching for a parked bicycle on a busy street, we typically scour locations where bicycles tend to occur, such as near bike racks and light poles, and we avoid searching unlikely locations, such as the tops of buildings or cars. How might these learned associations be acquired? We investigated this question using a series of visual search tasks. Specifically, we examined whether people can learn, over time, that target items are likely to occur within a particular category of objects (e.g., animals or dessert food). Participants searched through displays containing four categories of items, each localized to a particular quadrant of the display. One category was predictive; it always contained the target (e.g., the target always appeared near animals). Targets were randomized on each trial, and were unrelated to the category of images in which they were associated. Several combinations of categories were presented randomly across trials, each with a different predictive grouping. In order to verify that participants were learning to associate categories with targets and not simply relying on spatial cueing, we also included a condition wherein each category's quadrant location was randomized. In both conditions, participants found targets more quickly when a specific category always contained the target, compared to a control condition where no category was predictive of the target location. These results indicate that (1) people learn arbitrary associations between item identities relatively quickly, and (2) this category learning is independent of learning repeated spatial locations, and can be used to help guide the eyes to relevant items in the environment.

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53.554 Contextual cueing effect without eye movements

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Visual search performance is facilitated when fixed spatial configurations are presented repeatedly, an effect known as contextual cueing (Chun & Jiang, 1998). Previous studies revealed that the main contributing factor in contextual cueing is reduced number of saccades in repeated displays (Peterson & Kramer, 2001a; Zhao, Liu, Jiao, Zhou, Li & Sun, 2012). It is possible that fewer saccades in the repeated display reflect that people might learn how to move their eyes in those displays. In the current study, we investigated whether the contextual cueing effect could be obtained without eye movements. Participants were asked to search for a rotated T target among L distracters, and judge whether the target was rotated to the left or right. Two different set sizes (8 and 12) were used in the experiment. Participants were randomly assigned to one of two groups: with-eye-movement or without-eye-movement group. Participants in the without-eye-movement group were instructed to fixate on the center of the display and forbidden to move their eyes during the visual search task, while participants in the with-eye-movement group could freely move their eyes. The results of the with-eye-movement group showed a significant contextual cueing effect in set size 8 displays and a marginal contextual cueing effect in set size 12 displays. Furthermore, the results of the without-eye-movement group also showed a significant contextual cueing effect in both set size 8 and 12 displays. Effect sizes of contextual cueing were not significantly different across two groups. The participants in both groups could not recognize the repeated display. These results indicate that contextual cueing is robustly obtained without eye movements, suggesting that spatial configuration could be implicitly learned regardless of how to move eyes.

53.555 **Search templates can be adapted to the context, but only for unfamiliar targets.** Mary Bravo[1](mbravo@crab.rutgers.edu), Hany Farid[2]; [1]Psychology, Rutgers-Camden, [2]Computer Science, Dartmouth College

When observers search repeatedly for a target in a particular context, they learn a target template that is optimized for that context. If the same object is encountered in a different context, observers may learn a different target template. Can observers learn multiple templates for the same object and switch among these templates depending on the context? In an earlier study, we trained observers to search for a target in three contexts (three types of distractors). We then intermixed the contexts and found that search for the target was faster when observers were given a cue that allowed them to anticipate the context. We concluded that observers were switching their target template depending on the context (VSS 2012). This year, we ruled out the alternative explanation that observers use the cue to suppress the context. To do this, we repeated the experiment but randomly varied the target across trials. The context cue no longer benefited search, supporting the idea that observers used the context cue to switch their target template rather than suppress the context. We also tested whether observers could develop multiple search templates for a target that was already very familiar. We again repeated our original experiment, but we first pre-trained observers to discriminate the target from a large set of highly similar objects. This pre-training eliminated the effect of the context cue. In total, our results indicate that observers can develop context-specific search templates for unfamiliar targets. If observers have a pre-existing representation of the target, however, they seem unable to adapt their target template to the context.

53.556 **Is False Pop Out Really Pop Out? Evidence from RT functions.** Kimberley Orsten[1](kdo@rice.edu), James Pomerantz[1]; [1]Department of Psychology, Rice University

False Pop Out occurs when a distractor(s) in a visual search display poses as a target by drawing responses away from the actual target. It has been observed in classic singleton displays with homogeneous distractors and in heterogeneous displays where basic features differences would have led classic visual search theories (FIT, GS) to predict otherwise. It has also been observed in a pure form: in 3-item displays wherein one item is metameric with the second but anti-metameric with the third. This results in one of the distractors (i.e., one of the two identical items in the display) being perceived as the unique target almost 100% of the time. While FPO has been observed in displays varying in size and stimulus composition, the question remains as to whether these displays can produce the RT functions (specifically flat RT slopes as a function of set size) indicative of classic pop out. The results from a controlled experiment specifically looking at RT functions for FPO will be presented as converging evidence for our hypothesis that pop out does not result from basic feature differences in displays, but rather is the result of broken emergent features (specifically, symmetry) in displays that contain inter-stimulus configural relationships (i.e., displays processed as Gestalts). This hypothesis is born from the Theory of Basic Gestalts (Pomerantz and Portillo, 2011), which has demonstrated that when parts configure, unique-item search can be as efficient as differentiating black from white (Pomerantz, Sager & Stoever, 1977), and that these configural superiority effects remain stable with increasing display set sizes. If configurations can reliably improve unique target search, they should also reliably provide for FPO across display sizes. That is, items that break symmetry will truly pop out, regardless of display set size and regardless of whether they are unique.

Scene perception: Neural mechanisms

Tuesday, May 20, 8:30 am - 12:30 pm
Poster Session, Pavilion

53.557 **Temporal consistency of multi-voxel patterns for repeated scenes** Thomas O'Connell[1](thomas.oconnell@yale.edu), Emily Ward[1], Marvin Chun[1,2]; [1]Department of Psychology, Yale University, [2]Department of Neurobiology, Yale University School of Medicine

Multi-voxel pattern similarity predicts subsequent memory for visual stimuli (Xue et al., 2010; Ward et al., 2013), suggesting that pattern similarity tracks the stabilization of visual information into familiar, retrievable representations. How consistent are multi-voxel patterns across multiple repetitions of the same visual stimuli? To investigate this question, we scanned 10 participants while they viewed images depicting natural scenes. Each image was repeated four times, allowing us to measure pattern similarity across multiple exposures within three scene-selective regions of interest (ROIs): the parahippocampal place area (PPA), the retrosplenial cortex (RSC), and the occipital place area (OPA). To explore how repeated exposure modulates pattern similarity, we calculated pattern similarity sequentially between each exposure (e.g. between first and second presentation, between second and third presentation, etc.). We found that the overall degree of pattern similarity differed across ROIs, with the OPA showing the highest degree of similarity, followed by the PPA, then by the RSC, which showed the lowest. Additionally, we found that exposure did not modulate pattern similarity in the PPA and the OPA. However, in the RSC we found that pattern similarity was significantly reduced by exposure. Differences in the magnitude of pattern similarity and the modulatory role of exposure across ROIs indicate that these regions may be differentially implicated in behavior, such as visual memory.

53.558 **Anterior to posterior parahippocampal organization of scene information** Elissa Aminoff[1](elissa@cnbc.cmu.edu), Michael Tarr[1,2]; [1]Center for the Neural Basis of Cognition, Carnegie Mellon University, [2]Department of Psychology, Carnegie Mellon University

Scenes can be described in terms of both their contents and their spatial relations. For example, a bathroom typically contains both a toilet and a sink, as well as a mirror placed above the sink. A brain area within the parahippocampal-lingual region (PLR), often referred to as the parahippocampal place area, is thought to be critical for processing such information within scenes. Here, we demonstrate that the PLR mediates scene processing through mechanisms of associative processing. Participants were trained to learn novel associations between meaningless shapes, analogous to associations between objects, and novel associations between positions within a grid, analogous to spatial relations within a scene. To examine the functional role of such associative processing in cortical scene representation, we used fMRI to compare the BOLD patterns elicited for everyday scenes with the BOLD patterns elicited for the trained, novel associations. Overall, the novel associations were processed by the same neural structures as scenes. Critically, this functional similarity was organized according to the domain of the association along an anterior to posterior axis within the PLR. That is, the BOLD pattern was similar between scenes and the associations between shapes in anterior regions of the PLR – a relationship not evident in posterior regions. In contrast, the BOLD pattern was similar between scenes and the associations between locations in posterior regions of the PLR – a relationship not evident in anterior PLR. In sum, our results provide both an account for how scenes are encoded within the cortex, and an account of the specific functional mechanisms that support this encoding. As such, insight into how different forms of associative processing give rise to the neural mechanisms underlying scene representation.

Acknowledgement: Office of Naval Research MURI contract N000141010934

53.559 **Supervoxel parcellation of visual cortex connectivity** Christopher Baldassano[1](chrisb33@cs.stanford.edu), Diane M. Beck[2], Li Fei-Fei[1]; [1]Computer Science, Stanford University, [2]Psychology, University of Illinois at Urbana-Champaign

New large-scale studies using fMRI and dMRI have begun to reveal the fine-scale functional and anatomical connectome of the human brain. We have developed a new approach for understanding these massive datasets, allowing us to discover and visualize how connectivity changes over the entire cortical surface. Given a matrix describing the functional or anatomical connectivity strength between each pair of voxels, we apply a nonparametric clustering algorithm based on the distance-dependent Chinese Restaurant Process (ddCRP) in order to group voxels with similar connectivity properties into spatially contiguous "supervoxels." Our method is hypothesis-free, requires no specification of seed voxels, and produces a true parcellation of the brain into spatially-connected subregions rather than ignoring location information. We first validate the clustering method by dividing the Parahippocampal Place Area (PPA) into two subregions based on functional connectivity properties, matching previous work. We then cluster the 59,412-voxel whole-brain group functional and anatomical dataset from the Human Connectome Project, producing a ~200 supervoxel parcellation which provides a compact summary of the full connectivity matrix. For example, resting-state connectivity clustering in early visual cortex divides peripheral V1 from the foveal confluence of V1-V4, revealing that these regions have different functional connectivity patterns with other occipital regions (which match anatomical connectivity differences from probabilistic tractography). In addition to aiding in the discovery of more fine-grained connectivity patterns (allowing us to move beyond a localizer approach to region discovery), the learned parcellation is a general-purpose atlas that can be used to aid in other experiments such as whole-brain decoding. We plan to publicly release the connectivity atlas using an interactive 3D browser-based visualization tool, which will allow anyone to explore the rich connectivity structure of the brain.

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53.560 **Differential Selectivity for Spatial Frequencies in Anterior and Posterior PPA** Daniel Berman[1](berman.72@osu.edu), Dirk B. Walther[1]; [1]Department of Psychology, Center for Cognitive and Brain Sciences, The Ohio State University

The Parahippocampal Place Area (PPA) has been reported to consist of functionally distinct subregions: The anterior region is more related to high-level representations of scene content, whereas the posterior region is driven more by low-level stimulus properties (Baldassano et. al., 2013). How do these distinct regions differ in their sensitivity to spatial frequencies? On the one hand, PPA is sensitive to global image properties such as openness and naturalness (Park et al. 2011) or physical size and clutter (Park et al. in press), which are mainly determined by low spatial frequencies. On the other hand, PPA has been reported to respond more strongly to high than low spatial frequencies (Rajimehr et. al., 2011). In studies like these, spatial frequency content of stimuli is typically confounded with semantic information. Here we test spatial frequency sensitivity of PPA in an fMRI experiment with stimuli designed to be devoid of any coherent structure. We presented subjects with a series of visual patterns with narrowly defined spatial frequency bands centered around 0.2 to 18.1 cycles per degree and random phase. We found that anterior PPA was not significantly activated by these unstructured, semantically meaningless stimuli. Posterior PPA, however, was significantly activated. Moreover, the BOLD signal in posterior PPA was modulated by spatial frequencies. In contrast to the findings by Rajimehr et. al. we found that low spatial frequencies activated posterior PPA more strongly than high spatial frequencies in 13 out of 14 subjects. In order to explore the effect of semantic information on spatial frequency selectivity we are performing a follow-up study using frequency-filtered images of natural scenes. We will present results from a univariate analysis as well as decoding of scene categories from activity patterns in anterior and posterior PPA, separately for high-pass and low-pass filtered images.

53.561 **Categorical judgments of ambiguous scenes are controlled by neural activity in both LOC and PPA** Sean MacEvoy[1](sean.macevoy.1@bc.edu), Drew Linsley[1]; [1]Department of Psychology, Boston College

Behavioral studies indicate that scene categorization draws heavily upon analysis of scenes' spatial properties, such as three-dimensional layout (Greene & Oliva, 2009) as well as the kinds of objects scenes contain (Biederman, 1972; Davenport & Potter, 2004; Joubert et al., 2007). fMRI studies have identified distinct regions of ventral-temporal (VT) cortex that appear to process these features, notably the parahippocampal place area (PPA) for scenes' spatial properties and the lateral occipital complex (LOC) for their object contents. Although activity patterns in these regions correspond to the identities of viewed scenes (Walther et al. 2009, MacEvoy & Epstein, 2011), the extent to which perceptual judgments of scene category are determined by neural activity in these areas has remained unclear. This is particularly true of LOC, disruption of which has been shown to improve scene categorization accuracy even while degrading object recognition (Mullin & Steeves, 2011). To directly measure the influence of VT areas on scene category judgments, we used fMRI to record patterns of brain activity while observers categorized computer-generated scenes as bathrooms or kitchens; each scene was either unambiguously a member of one of these categories by virtue of both spatial properties and object contents, or was configured to be completely category-ambiguous. Observers were periodically instructed to base their decisions on either scenes' spatial properties or object contents. A classifier trained on responses to unambiguous scenes successfully predicted observers' categorical judgments of ambiguous scenes from the multivoxel activity patterns evoked in LOC and PPA. Crucially, predictions by LOC patterns were more accurate when observers were instructed to base judgments on scenes' objects, while those by PPA were more accurate for judgments based on scenes' spatial properties. These differentials are inconsistent with LOC and PPA patterns simply following observers' judgments, and instead indicate a significant dependence of judgments on neural signals in these regions.

53.562 **TMS to object-selective LO enhances fMR adaptation to scenes in the PPA** Sara Rafique[1](srafique@yorku.ca), Lily Solomon-Harris[1], Jennifer Steeves[1]; [1]Department of Psychology and Centre for Vision Research, York University, Toronto, ON, Canada

Damage to object-selective lateral occipital cortex (LO) results in impaired object recognition as evidenced in patients with object agnosia. We recently showed that transcranial magnetic stimulation (TMS) to LO disrupts object processing but enhances scene processing (Mullin & Steeves, 2011). This behavioural dissociation is mirrored in reduced BOLD signal at area LO subsequent to TMS to LO and increased BOLD signal in the scene-selective parahippocampal place area (PPA) (Mullin & Steeves, 2013). We performed consecutive repetitive TMS - fMRI using an fMR adaptation paradigm to determine response properties of object and scene processing regions following TMS to left LO compared to baseline. Participants viewed blocks of variant and invariant objects and scenes. At the TMS target site release from adaptation still occurred when viewing objects, and in the PPA release from adaptation was increased when viewing scenes. These findings suggest that despite disruption to area LO from TMS, it continues to differentiate objects. Remote areas in the network, specifically the PPA, benefit from disruption to LO with enhanced response properties.

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53.563 **Mapping natural and texture scene representations across the visual system** Jiye G Kim[1](jiyekim@princeton.edu), Sabine Kastner[1,2]; [1]Princeton Neuroscience Institute, Princeton University, [2]Department of Psychology, Princeton University

Recent neuroimaging studies have shown that scene category information is represented in the patterns of responses in scene-selective areas. What remains poorly understood is what features of scenes contribute to this information and how scene representations differ across scene and non-scene selective areas. In a series of behavioral experiments, we demonstrated that higher-order image statistics extracted from natural scenes provide meaningful category information, suggesting these features as the basis for the neuroimaging findings. Here, we used fMRI to investigate the transformation of scene representations across the visual hierarchy elicited by natural and synthesized texture scenes that have preserved higher-order image statistics from the intact scenes (Portilla & Simoncelli, 2000). To test for the robustness of representation, we manipulated attentional demands by either instructing subjects to passively view or classify rapidly presented scenes. We examined category (beach, city, or forest) and format (intact or texture) information across 27 functionally defined regions including areas in the early visual, category-selective (e.g., PPA) and topographically organized fronto-parietal cortex (e.g., FEF and IPS). Early visual areas consistently showed no category or format information across different task demands. Rather, the pixel-energy and gabor-filter models best predicted their responses. Under passive viewing, responses in scene-selective areas (PPA, TOS and RSC) were best predicted by image format, and to a lesser extent, category information. With attention, these differences were markedly reduced. Responses in fronto-parietal cortex were also best predicted by image format under passive viewing. However, with attention, fronto-parietal responses were best predicted by task demands irrespective of category and format. Together these results demonstrate a gradual transformation of the representations of scene information across the visual hierarchy and that category information obtained from image statistics is dynamically represented under different task demands.

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53.564 **Functional connectivity between object- and space-encoding brain regions during scene viewing** Drew Linsley[1](linsleyd@bc.edu), Sean MacEvoy[1]; [1]Psychology Department, Boston College

Behavioral data suggest that visual scene categorization draws heavily upon analysis of scene spatial properties, such as three-dimensional layout (Greene & Oliva, 2009). At the same time, the perceived category of a scene is strongly influenced by the kinds of objects scenes contain (Davenport & Potter, 2004; Joubert et al., 2007; MacEvoy and Epstein 2011). We recently

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used fMRI (Linsley & MacEvoy, VSS 2013) to demonstrate that these two routes to scene recognition converge, at least partially, in parahippocampal place area (PPA), an area of ventral-temporal cortex previously shown to be sensitive to scenes' spatial properties. Along PPA pattern dimensions yoked to scene spatial properties, scenes possessing extreme spatial properties were encoded as more similar to their category average when category-informative objects were visible versus masked. This "centripetal" bias may improve scene recognition accuracy by bringing scenes' encoded spatial properties into register with those expected from their object contents. In the present study, we applied a novel information-based functional connectivity analysis to identify brain regions participating in the generation of centripetal bias. Cortical volumes collected during presentation of extremely small and large bathrooms, both with informative objects visible and masked, were passed to an iterative whole-brain MVPA searchlight procedure to identify voxel clusters containing information about object-masking state. For each such cluster, we asked how well trial-by-trial scores extracted along pattern dimensions corresponding to scenes' object-masking state explained trial-wise variability of PPA centripetal bias. Similar to previous studies of PPA functional connectivity, our analysis revealed participation by clusters in the visual system and default-mode network (Baldassano et al., 2013). Among visual areas, the greatest contribution to PPA was made by clusters within lateral occipital complex (LOC), a region linked to object processing. These results reveal a functional network supporting crosstalk between object- and spatial property based routes to scene categorization.

53.565 Effect of RMS contrast normalization on the retinotopic processing of spatial frequencies during scene categorization

Stephen Ramanoel[1,2,4](stephen.ramanoel@upmf-grenoble.fr), Louise Kauffmann[1,2], Nathalie Guyader[3], Alan Chauvin[1,2], Cédric Pichat[1,2], Michel Dojat[4], Carole Peyrin[1,2]; [1]Univ. Grenoble Alpes, LPNC, F-38040, Grenoble, [2]CNRS, LPNC UMR5105, F-38040 Grenoble, [3]Univ. Grenoble Alpes, GIPSA-lab, F-38402 Grenoble, [4]INSERM U836, GIN, F-38706 Grenoble

Since there is considerable evidence suggesting that visual perception is based on spatial frequencies (SF) processing, a growing number of studies investigate the cerebral regions involved in the processing of low and high SF (LSF and HSF) information in complex visual stimuli (such as scenes). LSF and HSF stimuli are created using low- and high-pass filters that respectively attenuates signals with frequencies higher and lower than a cutoff frequency. The contrast is reduced in HSF relative to LSF images. Thus, recent fMRI studies normalized root mean square (RMS) contrast in image in order to avoid that differential cortical activations in LSF and HSF processing might be due to contrast differences. In the present fMRI study, we investigated whether RMS contrast normalization induced change in retinotopic processing of SF during scene categorization. For this purpose, participants performed a categorization task using large black and white photographs of natural scenes filtered in LSF, HSF and non-filtered (NF) scenes, in eight block-designed functional scans. In four functional scans, both mean luminance and RMS contrast of LSF, HSF and NF scenes were equalized, while in the other four functional scans only the mean luminance was equalized. When RMS contrast was not normalized, results showed that LSF (relative to HSF) scenes elicited activation in the anterior half of the calcarine fissures linked to the peripheral visual field, whereas HSF (relative to LSF) scenes elicited activation in the posterior part of the occipital lobes, which are linked to the fovea, according to the retinotopic property of visual areas. However, RMS contrast normalization drastically increased activation for HSF scenes only, such as no significant activation was obtained for LSF scenes compared to HSF scenes. Our study suggests that RMS contrast normalization should be used with caution when investigating the neural basis of SF processing in retinotopic areas.

53.566 Decoding the spatial scale of information in visual cortex

Luca Vizioli[1](Luca.Vizioli@glasgow.ac.uk), Lucy Petro[1], Lars Muckli[1]; [1]Institute of Neuroscience and Psychology, Center for Cognitive Neuroimaging, University of Glasow

Functional brain imaging has a spatial resolution in the range of millimetres, too low to directly capture the columnar substructures of visual cortex. However, multi-voxel pattern analysis (MVPA) may recover columnar-grained, micro-level features such as orientation preference. This claim has recently been challenged by the demonstration that decoding of microscopic features within visual cortex was in fact driven by macroscopic scale organization information, which co-varies with the former (Boynton, 2005, Freeman et al., 2011). The question of whether MVPA describes fine- or coarse-grained information pattern is therefore greatly debated. Here we propose a simple data driven approach to estimate the spatial scale of MVPA. We systematically investigated the impact of (mis)alignment upon support vector machine (SVM) classification performance on both 3T and 7T feedforward (i.e. visually stimulated) and feedback (i.e. visually non-stimulated) signals in V1 elicited by natural scene stimuli (Smith and Muckli, 2010). We simulated different extents of misalignment across functional runs by parametrically shifting our region of interest (ROI) one to five voxels in both directions along all three axes. The artificially misaligned ROis were then grouped according to number of voxels shifted (ranging from 0 to 5), regardless of direction. We trained an SVM classifier on the original and tested it on the misaligned data, independently per misalignment percentage. Our results illustrate a significant drop in SVM classification performance as a function of misalignment. The SVM performance curve, best described by a non-linear model, was characterised by a steep decrease in classification performance for the initial shift (i.e. 1 voxel), attenuating over larger shifts. As well as being of interest to all researchers implementing an unsupervised learning algorithm across functional runs, these results indicate that multi-voxel patterns activity hold both fine as well as more coarse grained neural information.

53.567 The Topographic Organization of Scene-Selective Regions in the Human Brain is Closely Linked to the Statistical Properties of the Image

David Watson[1,2](dw545@york.ac.uk), Tom Hartley[1,2], Timothy Andrews[1,2]; [1]Department of Psychology, University of York, UK, [2]York Neuroimaging Centre, UK

Scene-selective regions play a key role in the perception and recognition of the visual world. However, the principles that govern the topography of these regions have not been fully resolved. In this study, we directly compare the relative importance of low-level image properties and high-level scene category on the organization of scene-selective regions. fMRI responses were measured while 24 participants viewed images of two categories of scene: indoor and natural. Images of scenes were filtered in spatial frequency to generate four stimulus conditions: (1) indoor, high-pass; (2) indoor, low-pass; (3) natural, high-pass; (4) natural, low-pass that were presented in a blocked design. Scene-selective regions were defined in a localizer scan by comparing the response to intact and scrambled scenes. Scene-selective regions included the PPA, RSC and TOS. The patterns of response to each of the four conditions were compared using correlation based MVPA. Our prediction was that if high-level categorization is important, then the pattern of response to conditions that have the same category should be higher than to conditions that contain the same spatial frequency. On the other hand, if low-level image properties are important, the pattern of response to conditions with the same spatial frequency should be higher than to conditions with the same category. Using multiple regression, we found that both image properties and scene category were found to explain a significant proportion of the variance in the patterns of neural response. However, a significantly greater proportion of the variance in neural response was accounted for by the image properties. These results suggest that the topographic organisation of high-level visual regions is tightly coupled to low-level properties of the image.

53.568 Tracking the dynamic representation of a complex visual scene using Bubbles

Robin Ince[1](robin.ince@glasgow.ac.uk), Nicola Van Rijsbergen[1], Stefano Panzeri[1,2], Philippe Schyns[1]; [1]Institute of Neuroscience and Psychology, University of Glasgow, Glasgow, UK, [2]Center for Neuroscience and Cognitive Systems @UniTn, Istituto Italiano di Tecnologia, Via Bettini 31, 38068 Rovereto, Trentino, Italy

Understanding the spatio-temporal neural dynamics underlying the processing of information in complex visual scenes is critical to the study of high-level visual function, decision making, perception as well as many other brain functions (Gosselin&Schyns, 2002). To address this question we used a perceptually bi-stable natural scene (a segment from Dali's "Slave Market") together with the bubbles paradigm (Gosselin&Schyns, 2001; Smith et al. 2006) in an MEG experiment. On each trial we sampled regions of the image in five different 1-octave spatial frequency bands using Gaussian bubbles. The subjects report their perception of the scene in each trial. We performed an ICA-based source analysis on the MEG data. For each source, and at each time point, we quantified (using Shannon information) the strength of the relationship between pixel visibility and the MEG response (bandpassed 1-40Hz) for each pixel in each spatial frequency band. We performed Non-negative Matrix Factorization (NMF) on this set of pixel-MEG information images to obtain a parsimonious parts-based representation of the regions of the visual stimulus that modulate neural activity. Crucially, these components include both behaviorally relevant information (which can be identified by correlating pixel visibility directly with the behavioral response) as well as parts of the stimulus space that are not related to the subject's perceptual responses but are nevertheless represented in the brain. We used these components as spatial filters – applied to the single trial bubble masks – to reduce the dimen-

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sionality of the stimulus space and enable us to track directly the neural representations of these stimulus regions. Preliminary results reveal effects such as a lateralization of early neural representation of high spatial frequency behaviorally relevant information and demonstrate the feasibility of this methodology for rigorously quantifying the spatio-temporal dynamics of neural representations of complex natural images during behavior.

53.569 **Neural coding of image blur assessed by fMRI** Katherine Tregillus[1](kemtregillus@gmail.com), Lars Strother[1], Gideon P. Caplovitz[1], Michael A. Webster[1]; [1]Department of Psychology, University of Nevada, Reno

Many visual attributes appear to be encoded by a norm-based code in which the stimulus is represented by how it deviates from an average or neutral value (the norm). One prediction of these codes is that neural responses should be weaker for stimuli near the norm and stronger for uncharacteristic stimuli, a pattern that has been shown for a variety of stimulus dimensions. For example, BOLD responses are weaker for average than distinctive colors, faces, or voices. We used rapid event-related fMRI to determine whether a similar pattern of BOLD responses occurs in visual cortex for image blur, which behaves functionally like a norm-based dimension representing blurred or sharpened variations relative to a norm of "in focus." We presented observers with achromatic images of natural scenes, filtered by varying the slope of the log amplitude spectra from -1 (strongly blurred) to +1 (strongly sharpened) relative to the original slope. RMS contrast was equated to the original after filtering. In V1 there was higher activation for the in focus images than for the sharpened or blurred images. Similar patterns were observed in extra-striate areas, but to a lesser degree. The higher overall activation in V1 and other visual areas for focused images is inconsistent with an explicit norm-based coding for image focus, and could imply an implicit neural signature (e.g. distribution of responses across frequency-tuned channels) or one that occurs subsequent to retinotopic visual cortex. We also performed a whole-brain GLM to search for regions showing BOLD responses consistent with an explicit norm-based model. The results of this analysis suggest that, although norm-based coding was not evident in retinotopic cortex, it may nevertheless be instantiated in higher cortical areas.

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53.570 **Exploring the processing of the shape and material properties of scenes and objects in human visual cortex** Jonathan S. Cant[1](jonathan.cant@utoronto.ca); [1]Psychology Department, University of Toronto Scarborough

Recently, I demonstrated that the scene-sensitive PPA is more active for judgments of the material properties of objects (whether an object is made of soft or hard material; Cant & Goodale, 2011), compared to judgments of object shape. This appears inconsistent with the view that PPA is specialized for processing scenes, since the single objects used did not invoke scene imagery. But material-property judgments are important in scene processing as they can affect the strategies used to recognize and navigate through an environment (e.g., soft/hard terrain affects the posture and stability used to navigate through a scene). Thus, the material-property task used previously may have invoked a type of processing in PPA that is distinct from its role in processing the geometry of scenes. Specifically, these findings suggest that PPA represents scenes by processing both spatial (shape) and non-spatial (material) visual features. To investigate this possibility, I used fMRI to examine activity in PPA while participants made shape and material-property judgments of both objects and scenes (images consisted of a central object located within an indoor scene). I also examined activity in LOC, to explore if this object shape-sensitive region is also involved in processing the shape of scenes. Interestingly, judgments of object shape produced the highest activation in LOC (compared with judgments of scene shape, scene material, and object material, which did not differ), demonstrating that LOC is not a general-purpose shape-processing region. In PPA, activation was higher for judgments of object material compared with object shape, replicating previous results. But importantly, activation for both shape and material judgments of scenes was higher than activation for judgments of object features. This demonstrates that PPA does indeed process both spatial and non-spatial visual features, but importantly, this processing is specialized for visual features of scenes, not single objects.

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53.571 **Manual versus automatic segmentation of functional regions of interest: Effects on multi-voxel pattern analysis and repetition suppression** Andrew Serger[1](serger.3@osu.edu), Thomas O'Connell[2], Dirk Walther[1]; [1]Department of Psychology, Center for Cognitive and Brain Sciences The Ohio State University, Columbus, Ohio, 43210, USA, [2]Department of Psychology, Yale University, New Haven, Connecticut, 06520, USA

Manual segmentation of regions of interest (ROIs) has been a source of inconsistency across the literature, often with individual labs varying in their specific procedures. Recently, Julian et al. (Neuroimage 2012) developed a method of algorithmically segmenting functionally defined ROIs in the ventral visual pathway and validated their method with linear activity contrasts. Multi-voxel patterns, however, might be more sensitive to the specific localization method than linear contrasts. We explored how manually and automatically generated ROIs affect multi-voxel pattern analysis (MVPA) and repetition suppression (RS), two methods frequently used to probe high-level visual representations. We systematically explored different methods of localizing ROIs along the ventral visual stream and compared the morphology of the resulting ROIs. We then measured the effects of the localization methods on MVPA and RS using data from a recent study of natural scene representation from our lab (O'Connell et al., VSS 2013). We found that different localization methods gave consistent results with few minor exceptions. This finding imbues confidence in using an objective and fully automated method for identifying ROIs, like the one proposed by Julian et al., for both univariate and multivariate analyses. Mass adoption of an automated ROI segmentation procedure should lead to improved reproducibility and comparability of results between different labs, while drastically reducing experimenter bias in the localization process by removing the necessity of manually adjusting parameters on a subject-by-subject basis.

53.572 **Decoding culture from the human primary visual cortex** Junpeng Lao[1](junpeng.lao@unifr.ch), Luca Vizioli[2], Lars Muckli[2], Roberto Caldara[1]; [1]Department of Psychology, University of Fribourg, [2]Centre for Cognitive Neuroimaging, Institute of Neuroscience and Psychology, University of Glasgow

Humans have invented and transmitted distinct symbolic systems (i.e., language and numbers) over the course of evolution. As expected, these marked cultural differences have found subtle specific signatures in the brain. More recently, it has been shown that culture has also the potency to modulate the processing of non-symbolic visual information. Western observers preferably attend to focal objects and show a more efficient processing for local information, whereas Eastern observers display a global attention bias and are better at integrating information in the background. These cultural differences emerge in high-order functional areas, but it remains unclear whether culture also impact on primary visual cortex (V1). To this aim, we recorded fMRI signals in Western and Eastern observers while they were viewing complex real world scenes. We manipulated the nature of the diagnostic information present in the foveal and peripheral vision. The images contained either a focal object within 2° of visual angle, or depicted scenes with no meaningful information in the foveal area. We mapped individual V1s and extracted multivoxel patterns as a function of visual field eccentricity before entering them into a multivariate classification analysis. Our results revealed that the foveal but not the peripheral area of V1 carries information that can discriminate objects from scenes in Westerners. In contrast, scenes but not objects could be accurately decoded in the region representing peripheral vision in Easterners, with equal classification performance for both visual categories in the foveal area. The human V1 contains specific information about high-order cognitive processes in vision. This particular non-symbolic visual mapping provides an original mean to uncover culture in humans.

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Multisensory processing: Neural mechanisms, somatosensory, vestibular

Tuesday, May 20, 8:30 am - 12:30 pm
Poster Session, Pavilion

53.573 Discrimination of Shapes and Line Orientations on the Tongue

Margaret Vincent[1](MargaretArlene@gmail.com), Hao Tang[2], Zhigang Zhu[2], Tony Ro[1]; [1]Department of Psychology, The City College and Graduate Center, CUNY, [2]Department of Computer Science, The City College and Graduate Center, CUNY

Visual substitution devices, such as the Brainport tongue stimulator, which converts visual images into patterns of electrotactile stimulation through a 20 x 20 electrode grid array on the tongue, provide promise for individuals with visual impairments. However, very few studies have systematically assessed the effectiveness of such devices in conveying visual information. In order to evaluate the usefulness of the Brainport device, we conducted four experiments that examined the ability to discriminate electrotactile stimuli presented for 500 ms on the tongue. Experiment 1 demonstrates that it is difficult to discriminate shape stimuli, regardless of whether the shapes are filled or outlined. Experiment 2 indicates that a training block of 200 trials with accuracy feedback does not improve performance. Experiment 3 suggests that line orientations that differ by 30-degree angles are also difficult to differentiate. Finally, Experiment 4 shows that subjects can discriminate between line orientations that differ by 45-degree angles (i.e., three different line orientations). These experiments indicate that the tongue's discrimination abilities may not be adequate enough to use the Brainport device for object recognition, however, it might be useful for providing three-alternative discrimination information, which might be useful for purposes such as navigation.

Acknowledgement: NSF

53.574 Increased Experience with an Unfamiliar Language Decreases Fixations to the Mouth During Encoding

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Previous research has shown that infants viewing speaking faces shift their visual fixation from speaker's eyes to speaker's mouth between 4-8 mo. (Lewkowicz and Tift, 2011). It is theorized that this shift occurs in order to facilitate language learning, based on audiovisual redundancy in the speech signal. In a recent study, we found that adult participants gazed significantly longer at speaker's mouths while seeing and hearing unfamiliar language compared with seeing and hearing their native language (VSS, 2013). These findings suggest that there may be a mechanism, common to both infant and adults perceivers, in which gaze fixations to a speaking mouth are increased in response to the uncertainty in the underlying speech. If so, increasing familiarity with a speech signal may reduce this tendency to fixate the mouth. To test this, the current study investigated the effect of familiarization to non-native language on the gaze patterns of adults. We presented English-speaking, monolingual adults with videos of a female reciting short sentences in Icelandic. To ensure they were encoding the speech, participants performed a simple task in which they were presented with video clips of two different sentences, followed by an audio-only recording of one of the sentences, and had to identify whether the first or second video clip corresponded to the audio. In order to familiarize participants with the utterances, the same set of sentences were repeated, in pseudo-random order, across consecutive 'repetition' blocks. In addition, we presented 'novel' blocks, using sentences not previously presented. We found that the proportion of fixations directed at the mouth decreased for repetition blocks, but not for novel blocks. These results suggest that familiarity with utterances, even in a non-native language, serve to reduce auditory uncertainty, leading to reduced mouth fixations.

53.575 TMS over the right parietal cortex disrupts audiovisual binding in the line motion illusion

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In the line motion illusion (LMI), a static bar presented all at once is perceived to shoot out from one end where a preceding cue was presented (Hikosaka et al., 1993). The LMI can be induced by either a visual or auditory cue (Shimojo et al., 1997). Though the LMI with visual cues has been widely studied, little is known about the processes that underlie the audiovisual binding when auditory cues are used to induce illusory visual motion. Here, we used transcranial magnetic stimulation (TMS) to investigate the cortical mechanisms of multisensory integration between auditory and visual stimuli in the LMI. Ten subjects were presented with an auditory cue at one of eleven times around the presentation of the bar starting at 500ms before to 500ms after the bar, separated by 100ms intervals. Presenting the cue at a range of timings allowed us to obtain information of the timing of the crossmodal interaction between the auditory cue and bar. At the beginning of each trial, we applied triple-pulse TMS (20Hz at 60% intensity) over the right or left intraparietal sulcus (IPS), an area implicated in attention-related multisensory interactions (Klemen & Chambers, 2012), immediately before stimulus presentation. Subjects had to report the direction the bar appeared to move, either toward or away from the cue. Subjects were also tested in a similar visual cue version of the task. We found that the LMI was only disrupted when TMS was applied to the right IPS with auditory cues, but not with visual cues. No effect was found when TMS was applied to the left IPS with either cue modality. These results show the right IPS plays a crucial role in the audiovisual interactions in the line motion illusion and further clarify the role the parietal attention system plays in binding audiovisual events.

53.576 Contributions of the body and head to perceived vertical: Cross-modal differences

Lindsey Fraser[1](lfraser4@yorku.ca), Bobbak Makooie[1], Laurence R. Harris[1]; [1]York University

At whole-body tilts of 45°, a bias in the subjective visual vertical (SVV) towards the direction of tilt has been reported (the "A" or Aubert effect). This bias has been attributed to a tendency for the perceived direction of gravity to shift towards the longitudinal body axis (MacNeilage et al., 2007). However, it is unclear whether this bias exists in non-visual measures of gravity perception (e.g., Bortolami et al., 2006). Here we directly compared haptic (SHV) and visual (SVV) judgments of a rod's verticality relative to gravity. To assess the relative contributions of the head and body axes on verticality perception we varied body and head tilt independently. When the body was tilted 45° with the head upright, the SVV and SHV were both biased towards the direction of body tilt. When the body was upright with the head tilted 45°, the SVV bias was towards the head and increased in magnitude, but the SHV did not significantly differ from the gravity and body axes. Our findings agree with previous reports that SVV is biased primarily towards head position, but is also influenced to a lesser extent by body tilt. A novel finding is that biases of the SHV appear to be largely related to body orientation and not head orientation, potentially explaining some of the inconsistencies in the SHV literature. Clemens and colleagues (2011) have proposed two systems for estimating the direction of gravity, one using the head's position as a reference and the other using the body's position. Our results suggest the body system may play a stronger role in SHV than SVV, possibly because it is more computationally efficient to compare hand position to the body rather than the head.

53.577 Head Tilt Delineates Two Mechanisms of the Rod-and-Frame Illusion

Scott A. Reed[1](sreed@uoregon.edu), Melissa A. Farley[1], Paul Dassonville[1]; [1]Department of Psychology and Institute of Neuroscience, University of Oregon

The rod-and-frame illusion, in which a tilted frame causes an enclosed line to appear rotated in the direction opposite the frame, is thought to be driven by two separate mechanisms: 1) a visuovestibular distortion in the observer's perception of gravitational vertical, and 2) low-level orientation contrast effects brought about by mutually inhibitory populations of neurons that encode the respective orientations of the rod and frame. However, these two mechanisms are thought to contribute to the overall perceptual phenomenon of the illusion in a graded fashion, with the visuovestibular and orientation contrast effects somewhat stronger with larger and smaller frames, respectively. In past work (e.g., Dassonville & Williamson, VSS 2010), we have devised two sensorimotor tasks to independently measure these effects. The visuovestibular effect was assessed with the saccade-to-vertical task, with participants asked to make a saccade to the topmost point on a response circle contained within the tilted frame. The orientation contrast effect was assessed with the saccade-to-rod task, with participants asked to make a saccade to the point on the response circle intersected by the rod if it were extended upward. In the current experiment, we verified the selectivity of these tasks by having the participants perform with the head tilted, with the expectation that the tilted head would attenuate vestibular cues and thereby cause an enhanced reliance on the visual orientation cues that specifically drive the visuovestibular effect (see Prinzmetal & Beck, 2001). Indeed, head tilt magnified the illusion-related bias in the saccade-to-vertical task (especially with large frames), but had no effect on the magnitude of the bias in the saccade-to-rod task. These findings confirm that these two tasks can successfully isolate the

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visuovestibular and orientation contrast effects of the rod-and-frame illusion, and provide further evidence that head-tilt magnifies visuovestibular distortions but leaves low-level orientation contrast effects unaffected.

53.578 **Can't use sight? Don't go right!** Kayla Stone[1](kayla.stone@uleth.ca), Claudia Gonzalez[2]; [1]Department of Neuroscience, University of Lethbridge, [2]Department of Kinesiology, University of Lethbridge

Recently we have found that during visually-guided grasping tasks, individuals prefer to use their right hand to pick up an object, particularly if it is small in size. However, during haptically-guided (using touch) grasping tasks, a significant increase in left-hand use emerges, particularly when grasping small objects (which require finer discrimination). Is the increase in left-hand use due to a left-hand/right-hemisphere specialization for haptic discrimination? To address this question, blindfolded participants were instructed to haptically assess and replicate an array of small objects (LEGOs) as quickly and accurately as possible. Located on a building plate in front of the participant was an array of five different blocks to be replicated (reference array) using a closer array of ten blocks (sample array). Using hapsis, participants would choose from and remove the blocks needed from the sample array and place them onto a smaller fixed building plate directly in front of them, creating a replica of the reference array. Participants completed the task bimanually, or exclusively using the left or right hand (counterbalanced between participants). Measurements included time to complete each trial and the number of mistakes made by each hand per trial. Additionally, we measured the time each hand spent discriminating the arrays during the bimanual trials. Results showed that participants were fastest at completing each trial when they used both hands. However, for these trials participants made significantly more mistakes when compared to the left but not the right hand. Furthermore, participants spent significantly more time discriminating the blocks with their left hand during the bimanual trials. The results align with previous findings of a left-hand/right-hemisphere specialization for haptic discrimination, which may explain the increase in left-hand use for grasping without vision. Furthermore the results suggest that during a haptically-guided bimanual task, hemispheric cross-talk may interfere with performance.

Acknowledgement: NSERC, University of Lethbridge

53.579 **Visual-haptic integration for gloss perception** Wendy Adams[1](w.adams@soton.ac.uk), Iona Kerrigan[1], Erich Graf[1]; [1]Psychology, University of Southampton

Our perceptual system combines visual and haptic (touch) information to optimize estimates of 3D properties including slant (Ernst, Banks & Buelthoff, 2000) and size (Ernst & Banks, 2002). However, the integration of visual and haptic cues to material properties has been largely overlooked. Previously (Kerrigan, Adams & Graf, 2010), we reported that observers' gloss perception is modulated by the haptic properties of friction and compliance: objects that feel hard and smooth are perceived as glossier than those that feel soft and rubbery. The current study demonstrates that visual and haptic gloss cues are integrated at a perceptual level, resulting in visual-haptic metamers. First, observers completed an odd-one-out task with uni-modal stimuli. This allowed us to equate visual and haptic stimulus parameters in terms of discriminability. Observers then performed a similar odd-one-out discrimination task with visual-haptic objects. When visual and haptic gloss cues were varied in opposition to each other (e.g. visual gloss increased but the object felt more rubbery, relative to a standard stimulus), discrimination performance was poor: the two cues' effects partially cancelled out, resulting in reduced perceptual changes. This contrasted with improved discrimination when visual and haptic gloss cues varied concordantly (e.g. objects that were visually more glossy were also harder and more slippery). Although friction and compliance are not reliable predictors of gloss across our environment, the visual system appears to know and use a probabilistic relationship between these variables to inform material perception.

53.580 **The contribution made by gaze position to the integration between multisensory feedback and self-body sensations** Seiya Kamiya[1](kamiya.s.ac@m.titech.ac.jp), Takako Yoshida[1]; [1]TokyoTech

Whilst the importance of multimodal information is repeatedly highlighted for self-body sensations, the integration process of the multimodal information for these sensations is still unclear. We examined the contribution made by gaze position to the integration of multimodal information under the hypothesis that visual and haptic information should be within a spatio-temporal window of gaze and spatial attention to achieve the integration. To investigate the critical temporal delay for this window, we measured how visual feedback delay changes eye and hand behaviors and self-body sensations. Participants executed a block copying task that involved manually collecting and arranging colored blocks to duplicate a pattern observed on a delayed video image. As delay increased, the score of the questionnaire on self-body sensations decreased. This decay slope changed after a delay of approximately 350 ms, which was when distribution of fixation duration and hand velocity also showed qualitative change. These results suggested that participants' gaze and hand behaviors changed at this value. When the delay was relatively short, the hand position followed gaze position and thus shared the same movement patterns. However, when the delay was relatively long, this relationship collapsed, suggesting that visual and haptic feedbacks are not within the temporal window for the integration and thus participants relied on their haptic sense more heavily than vision to avoid attentive demand. Our results suggest that the 350 ms visual feedback delay is the critical point for changing the demand needed for multimodal process around gaze position. To examine the contribution of gaze position to multimodal binding or self-body sensations more precisely, we are currently conducting a gaze-contingent window experiment for the real-time video image, in which participants' central vision was replaced by delayed image, to investigate critical size of spatial window and its interaction with temporal window for intuitive operation.

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53.581 **Spatiotopic maps in calcarine sulcus of the congenitally blind** Petra Vetter[1](petra.vetter@unige.ch), Lior Reich[2], Amir Amedi[2]; [1]Dept. of Neuroscience, Medical School, University of Geneva, [2]Faculty of Medicine, Hebrew University of Jerusalem

Here we studied how congenitally blind subjects represent space in the brain and whether they have spatiotopic maps similar to the sighted. We asked 8 congenitally blind subjects to read specifically designed braille letters with a dot missing in either of the four corners of the braille grid (upper right, upper left, lower right and lower left) and to represent that part of space in their imagination while we acquired fMRI BOLD signals. Results show that functional maps corresponding to the four areas of space exist in the occipital pole close to calcarine sulcus. However, the coding of these maps differs across blind subjects and also differs from the coding of retinotopic maps in the sighted. The results suggest that visual brain structures evolved to represent space through visual input in the sighted can be rewired to represent space through tactile input in the congenitally blind

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53.582 **A neural correlate of intentionality persists in the parietal cortex of a patient without proprioception** Elizabeth Torres[1,2,3](ebtorres@rci.rutgers.edu), Kyuwan Choi[1]; [1]Psychology Department, Rutgers University, [2]Rutgers Center of Cognitive Science, [3]Rutgers Computational Biomedicine Imaging and Modeling Center

The posterior parietal cortex (PPC) has been identified as a critical node to encode the intention to move (Andersen and Buneo, 2002). Recently it has been asked whether or not this region encodes an abstract intentional signal, a signal independent of afferent inputs from active movements (kinesthetic re-afference) (Desmurget and Sirigu 2009, 2012). In this work we investigate this question in patient Ian Waterman (IW) who lost his sense of movement (proprioception) at 19 years of age due to large fiber neuropathy. IW replaced his sense of proprioception with vision and regained control of his movements. Yet he always has to predict ahead the sensory consequences of his actions, a forward-computation that is also thought to occur in the posterior parietal region (Mulliken et al., 2008). We compared the electroencephalographic (EEG) patterns of IW to those of 15 neurotypical participants as they mastered a Brain Computer Interface (BCI) and gained volitional-mental control of the direction of motion of an external cursor. We examined patterns of activation across different frequency bands and used synchronization metrics of phase locking value and phase lagging index to assess coupling patterns that self emerged during the learning progression. The participants were trained using visual feedback. A subset (including IW) was tested using auditory feedback as well, even though they never trained under this form of sensory guidance. We found coupling along the fronto-parietal networks that differed between controls and patient-IW. Specifically, as neurotypical participants improved the intentional mind-control of the cursor, they engaged the prefrontal cortex (PFC) with the highest levels of activation. In contrast, patient IW engaged the PPC with the highest levels of activation all throughout. These results strongly suggest that (1) the intentional signal in the PPC stands independent of re-afference and (2) The PFC typically encodes an externally-prompted intentional signal.

Acknowledgement: NSF

Tuesday AM

53.583 The development of multisensory integration is specific to a neuron's experience
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Neurons in the superior colliculus (SC) develop the capacity to integrate visual, auditory, and somatosensory information based on the animal's experience with concordant cross-modal cues. This elevates their multisensory responses over the component unisensory responses. When sensory experience is restricted in early life, neurons develop normal complements of multisensory neurons; but are unable to integrate cross-modal stimuli involving the deprived modality. Their responses to these cross-modal cue combinations are no greater than those to the component stimuli. What has not been known is whether experience leads to configurations that grant a neuron the general integrative capability to enhance responses to all cross-modal combinations to which it is sensitive, or if each must be learned separately. To investigate this issue we studied trisensory (visual-auditory-somatosensory) in normal animals, those reared in darkness, and those reared in constant masking noise. The results revealed that neurons learn to integrate cross-modal cues in a combination-specific manner. Thus, while trisensory neurons were able to integrate cross-modal pairs involving non-deprived senses, they were unable to integrate those involving a deprived sense. The findings indicate that developing multisensory integration capabilities does not involve a general change in processing capabilities, but one specific to each cross-modal configuration. The data also underscore the observation that the "default" plan instantiated in the absence of relevant experience renders a neuron responsive to multiple sensory modalities but unable to integrate them and thereby enhance the salience of the originating event. Supported by NIH grants EY016716 and NS036916 and the Tab Williams Foundation.

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53.584 Development of dorsal and ventral stream connectivity: A visuohaptic psychophysiological interaction study
R. Joanne Jao[1](rjjao@indiana.edu), Karin H. James[1], Thomas W. James[1]; [1]Indiana University

The neural substrates underlying multisensory visuohaptic object recognition have been studied extensively in adults, yet are only beginning to be explored in children. Brain regions implicated in visuohaptic object processing include the lateral occipital complex (LOC) and the intraparietal sulcus (IPS). Although a few studies have investigated functional connectivity between the visuohaptic dorsal and ventral streams in adults, the development of this connectivity for supporting recognition remains unknown. In the present study, three groups of participants (4 to 5.5 year olds, 7 to 8.5 year olds, and adults) were tested using BOLD fMRI during a block design comprising visual and haptic exploration of real objects and textures. To examine the development of task-dependent functional connectivity between the LOC and the IPS and other neural substrates, general psychophysiological interaction (gPPI) methods of analysis were implemented. Results indicated stronger connectivity (correlation strength) between the LOC seed region-of-interest (ROI) and the IPS in 4 to 5.5 year olds than in the older two groups for haptics. Similarly, the IPS seed region showed a stronger functional connection to the LOC for haptics in 4 to 5.5 year olds than in 7 to 8.5 year olds or adults; the 7 to 8.5 year olds and adults indicated comparable correlation strengths overall. Additionally, the correlations between the LOC seed ROI and aspects of the IPS for vision were weaker in adults than in either group of children. These findings show decreases in bi-directional functional connectivity strength between the LOC and the IPS with increasing age, suggesting that development involves gradual uncoupling of dorsal and ventral stream visuohaptic processing centers. Critically, there appears to be a transitional period between 4 and 8 years of age during which functional connectivity plateaus for haptics, but continues to develop for vision.

53.585 The representation of visual and somatosensory space in the superior colliculus of a human subject without an optic chiasm
David Ress[1](ress@bcm.edu), Michael S. Beauchamp[2], Chris Purington[3], Benjamin T. Files[4], Bosco S. Tjan[5]; [1]Neuroscience, Baylor College of Medicine, Houston, TX, [2]Neurobiology & Anatomy, University of Texas Health Science Center at Houston, TX, [3]Vision Science Graduate Group, University of California, Berkeley, [4]Neuroscience Graduate Program, University of Southern California, Los Angeles, CA, [5]Psychology, University of Southern California, Los Angeles, CA

A small number of humans are born without an optic chiasm. In these individuals, the entire visual field is represented in both cerebral hemispheres, unlike the contralateral organization in typically developed controls. We investigated the representation of visual and somatosensory space in the superior colliculus (SC) of a subject (age 23) with congenital achiasma. SC is a brainstem structure critical for spatial orientation. Methods: Visual stimulation was measured using a blocked protocol: the subject fixated while an expanding wedge of moving dots (150° polar angle, speed 2°/s) was presented for a single hemifield for 12 s, alternating with 12-s blank periods. In alternating runs, stimuli were presented in either the left or right hemifield. Stimuli were presented only to the subject's dominant (right) eye; the left eye was patched. To manipulate attention, the subject either performed a challenging task at fixation or at the peripherally located stimulus. Somatosensory responses were evoked using piezoelectric stimulation of one of the subject's palms, alternated with rest. Attention was focused on the stimuli using a challenging rate-discrimination task. High-resolution (1.2-mm) fMRI data were collected using a spiral sequence. Results: Visual stimuli of the right eye evoked strong responses only in the right colliculus; responses for both hemifields showed similar spatial patterns upon rostral SC. Directing attention onto the stimulus increased the stimulus-evoked response in right SC, and evoked a non-localized, somewhat delayed response over both colliculi. Somatosensory stimulation of the subject's dominant right palm produced significant activation in left SC; left palm stimulation produced both contra- and ipsilateral SC activation. Conclusions: In an achiasmatic subject, the SC ipsilateral to the stimulated eye represents both visual hemifields, much as in cerebral cortex. However, somatosensory stimuli are represented by the contralateral SC. The findings challenge the need for consistent spatiotopic maps in SC across sensory modalities.

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53.586 Visual brain areas predict haptic (and visual) behavioral similarities between novel objects
Haemy Lee[1](hello-stranger@nate.com), Hans Op de Beeck[2], Christian Wallraven[1]; [1]Brain and Cognitive Engineering, Korea University, [2]Biological Psychology, KU Leuven

Humans are highly adept at multisensory processing of object shape in both vision and touch - furthermore, unfamiliar objects with complex shape properties are learned easily in both modalities. Here, we used psychophysics and fMRI to investigate neural correlates of visual and haptic processing of novel, three-dimensional stimuli. The experiment used 9 objects that varied parametrically in shape, forming a cross in object-parameter space. First, two groups of participants judged object similarities either visually or haptically (90 trials, each n>30). Similarity ratings were averaged across participants to obtain one group similarity matrix in both modalities. The reconstructed behavioral space conformed well to the underlying object-parameter space in both modalities. After two days, we invited 11 participants from the visual group to perform an fMRI-experiment, consisting of two blocks of a 1-back recognition task. The first block was run visually in the familiar modality, whereas the second block was run haptically, thus in a new modality. Objects were presented successively in the scanner for 6sec (with an ISI of 16sec including response period). We selected anatomically-defined Brodmann areas BA17, BA18 as well as the localizer-defined lateral-occipital-complex (LOC) as regions of interest for a correlation analysis of behavioral similarity ratings with neural responses. Neural activations in each area were averaged across participants to obtain group visual and haptic neural similarity matrices. In the visual block, both BA18 ($r=.6585$ $p<.000$) and early visual cortex, BA17 ($r=.6875$ $p<.000$) showed high correlations with behavior. Interestingly, this correlation was found also for the haptic block for both BA18 ($r=.6135$ $p<.000$) and BA17 ($r=.463$ $p<.004$). Furthermore, neural responses in LOC correlated only for visual data, but not for haptic data. These results show clear involvement of early and higher-order visual areas in both visual and haptic tasks, indicating a complex network of brain areas involved in multisensory processing.

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53.587 **Long-term reorganization of auditory motion direction encoding as a result of early blindness** Fang Jiang[1](fjiang@u.washington.edu), G.C. Stecker[2], Ione Fine[1]; [1]Department of Psychology, University of Washington, Seattle, WA, [2]Hearing & Speech Sciences, Vanderbilt University Medical Center, Vanderbilt, TN

We recently showed that hMT+ responses to auditory motion after early blindness are associated with subjects' decisions about auditory motion (VSS, 2012). Using fMRI pattern classification, in sighted individuals the perceived direction of motion for both coherent and ambiguous auditory motion stimuli was accurately categorized based on BOLD responses within the right planum temporale (PT); whereas within early blind individuals auditory motion decisions were only successfully categorized based on responses within hMT+, and could not be categorized based on responses within the right PT. Here we examined auditory motion direction processing in sight recovery subject MM, who acquired vision during adulthood after becoming blind at age three. Despite severe losses in acuity, he has no known deficits in his ability to process visual motion and he shows normal hMT+ responses to visual motion localizer stimuli. More than a decade after MM receiving visual input as an adult, we found the same double dissociation in fMRI pattern classification performance in MM as for early blind subjects: we were able to classify the perceived direction of auditory motion based on BOLD responses within hMT+ but not within PT. Thus, cross-modal motion responses consequent on blindness are unlikely to be the result of short-term unmasking, and are more plausibly the result of long-term developmental alterations in the functional specialization of hMT+.

53.588 **Frontoparietal connectivity supports dynamic body representation** John Plass[1](johncplass@u.northwestern.edu), David Brang[1,2], Andrew Bryant[2], Satoru Suzuki[1], Zach Taich[2], Vilayanur Ramachandran[2], Marcia Grabowecky[1]; [1]Department of Psychology, Northwestern University, [2]Department of Psychology, University of California San Diego

Body representation processes underlie individuals' coherent sense of body ownership and knowledge of the spatial boundaries of the body. These experiences are highly dynamic, changing throughout development or due to damage and disease. Indeed, large individual differences exist in the ability to dynamically update one's body representation, typically measured with the rubber hand illusion. In this effect, watching touches applied to a rubber hand while receiving the same pattern of touches on one's own hand engenders the experience that the rubber hand is part of the body, providing a trait-like marker of body representation plasticity. Functional neuroimaging studies highlight the role of the intraparietal sulcus and ventral premotor cortex in this illusion, and body representation disorders are associated with reduced activity in similar regions in addition to altered connectivity between frontoparietal areas. However, it remains unknown whether subclinical reductions in connectivity in some individuals accounts for individual differences in body representation plasticity. Examining the relationship between neuroanatomical connectivity, as measured with diffusion tensor imaging, and the intensity of the rubber hand illusion, we identified a significant positive relationship between illusion intensity and the coherence of connectivity along the frontoparietal network, implicating this pathway in individual differences in body representation plasticity. Results suggest that multisensory body representation processes are facilitated by coherent connectivity in the frontoparietal network and that the presence of large individual differences in the rubber hand illusion may account for some individuals' susceptibility to body representation disorders.

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53.589 **Touching and tracing improve working memory for location and orientation** Stacey Parrott[1](staceyparrott2014@u.northwestern.edu), Mark Huntington[2], Marcia Grabowecky[1,3], Satoru Suzuki[1,3]; [1]Department of Psychology, Weinberg School of Arts & Sciences, Northwestern University, [2]Materials Science & Engineering, McCormick School of Engineering, Northwestern University, [3]Interdepartmental Neuroscience Program, Weinberg School of Arts & Sciences, Northwestern University

Growing evidence suggests that performing an action can enhance our perception of events related to that action (Schutz-Bosbach & Prinz, 2007). Here we show that working memory for location and orientation is enhanced by appropriate action. In the spatial working-memory task, participants viewed (for 3.5s) an array of four dots to remember their locations. In the orientation working-memory task, participants viewed an array of four oriented lines (each presented within an L-shaped frame to reduce grouping and to simulate a line graph) to remember their orientations. Participants either simply inspected the array (the visual-only condition), or touched the four dots or traced the oriented lines (the action condition). Following a 1s blank interval participants saw either an identical array or a changed array in which the location of one of the dots changed (in the spatial working-memory task) or the orientation of one of the lines changed (in the orientation working-memory task), and responded “change” or “no change.” The spatial and orientation working-memory tasks were blocked, and within each task the visual-only and action conditions were blocked. Action improved the change/no-change response accuracy in both the spatial and orientation working-memory tasks. To make sure that these improvements were not due to non-specific effects of action such as increased arousal or increased task engagement, we repeated the orientation working-memory task except that participants simply touched (rather than traced) the four oriented lines. If action facilitates working memory by providing stimulus-specific information, simply touching the lines should not improve orientation working-memory because, although touching visual items provides location information, it does not provide orientation information. We confirmed this hypothesis. These results suggest that task-appropriate actions, touching dots for encoding locations and tracing lines for encoding orientations, improve working memory in a task-dependent manner.

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Tuesday AM

Tuesday Afternoon Talks

3D Perception

Tuesday, May 20, 2:30 - 4:15 pm
Talk Session, Talk Room 1
Moderator: Johannes Burge

54.11, *2:30 pm* **3D surface tilt estimation in natural scenes from image cue gradients** Johannes Burge[1](jburge@mail.cps.utexas.edu), Brian C. McCann[1], Wilson S. Geisler[1]; [1]Center for Perceptual Systems, University of Texas at Austin

Estimating the 3D shape of objects is a critical task for sighted organisms. Thus, it is important to understand how different image cues should be combined for optimal shape estimation. Here, we examine how gradients of various image cues—disparity, luminance, texture—should be combined to estimate surface tilt in natural scenes. Surface tilt is the direction in which a surface is receding most rapidly; for example, the ground plane straight-ahead has a surface tilt of 90 deg. Estimating surface tilt is necessary for recovering surface orientation and 3D shape. To determine how image cues to surface tilt should be optimally combined, we collected a database of stereoscopic natural images with precisely registered range images, using a robotically positioned DSLR camera and laser range scanner. For each pixel in each registered image (~109 samples) we computed the gradients of range, disparity, luminance, and texture within a local area (0.6 deg). Then, we computed the conditional mean of the range-gradient orientation (the ground-truth surface tilt), given the orientations of the image gradients. These conditional means are the Bayes optimal (MMSE) estimates of the surface tilt given the image cues, and are free of assumptions about the shapes of the underlying joint probability distributions. A rich set of results emerges. First, the prior probably distribution over surface tilts in natural scenes exhibits a strong cardinal bias. Second, the likelihood distributions for disparity, luminance, and texture are each somewhat biased estimators of surface tilt. Third, the optimal estimates of surface tilt are more biased than the likelihoods, indicating a strong influence of the prior. Fourth, when all three image cues agree, the optimal estimates become nearly unbiased. Fifth, when the luminance and texture cues agree they often override disparity in the estimate of surface tilt, but when they disagree, they have little effect.

54.12, *2:45 pm* **Disparity Preferences in V1 Reflect the Statistics of Disparity in Natural Viewing** William Sprague[1,2](bill.sprague@berkeley.edu), Emily Cooper[3], Jean-Baptiste Durand[4,5], Martin Banks[2,1]; [1]Vision Science Graduate Group, University of California, Berkeley, [2]School of Optometry, University of California, Berkeley, [3]Department of Psychology, Stanford University, [4]Université de Toulouse, Centre de Recherche Cerveau et Cognition, Toulouse, France , [5]Centre National de la Recherche Scientifique, Toulouse Cedex, France

The efficient coding hypothesis predicts that disparity preferences in binocular V1 neurons should reflect the distribution of disparities observed during natural viewing. Several investigators have reported that the majority of disparity-selective V1 neurons prefer crossed (or near) disparity and argued that this bias reflects the natural distribution of disparities. To address these issues, we compared empirical measurements of disparity statistics (Cooper et al., 2013) with the preferred disparity of 620 V1 neurons measured in four well-known neurophysiological studies (Cumming, 2002; Durand et al., 2007; Gonzalez et al., 2010; Samonds et al., 2012). We unified the data by projecting into a common coordinate system (Helmholtz coordinates) and examined how horizontal- and vertical-disparity preferences vary with visual-field position. The empirical disparity statistics predicted that neurons in the lower visual field should be more likely to prefer crossed horizontal disparities, while those in the upper field should prefer uncrossed disparities. The distribution of preferences for neurons in the lower field is indeed shifted toward crossed disparities relative to neurons in the upper field. The crossed disparity bias of lower-field neurons may have previously been mistakenly generalized to the whole visual field due to over-sampling of the lower visual field (77% of neurons across these studies). We also predicted that neurons in the upper left or lower right field quadrants are more likely to prefer positive vertical disparities, while neurons in the other quadrants should prefer negative vertical disparities. We observed a small shift towards positive vertical disparities for neurons in the upper left and lower right. Unfortunately, there are not enough neurons in the other quadrants to determine if they have a negative disparity preference. Our analysis of V1 neurons is consistent with the hypothesis that the distribution of preferred disparities reflects the statistics of disparity across the visual field.

54.13, *3:00 pm* **Perceived depth in natural images reflects encoding of low-level depth statistics** Emily A. Cooper[1](eacooper@stanford.edu), Anthony M. Norcia[1]; [1]Department of Psychology, Stanford University

Seeing in 3D is typically understood as relying on a patchwork of visual depth cues. Accessing these cues requires computations that have challenged computer-vision algorithms and could only feasibly be performed by late-stage neural integration mechanisms. However, statistical analyses of natural scenes have revealed low-level luminance patterns that are predictive of distances, and that could be accessed by early-stage visual mechanisms with a low computational cost (e.g., Potetz & Lee, 2003; Su, Cormack, & Bovik, 2013). Optimal-coding models predict that the visual system should allocate its computational resources to exploit these patterns, and that this allocation should affect perceptional judgments. For example, darker points tend to be farther away than brighter points in natural scenes. This pattern is reflected in V1 cell tunings (Samonds, Potetz, & Lee, 2012). In the current work, we tested the model prediction that perceptual judgments will also be affected by this pattern. We asked if scenes conforming better to a "darker is farther" pattern are perceived as more 3D. We developed an image-processing algorithm that smoothly modulates luminance-depth patterns to make an individual image more or less consistent with natural scene statistics. This algorithm was applied to a set of photographs of natural and man-made scenes. Participants (n = 20) judged which version of a scene appeared more 3D. We compared the scene-statistics manipulation to a classic depth cue (binocular disparity). The results show that perceived depth agrees with an optimal coding prediction: versions of scenes with exaggerated luminance-depth patterns were seen as more 3D. The increase in positive 3D judgments caused by manipulating the scene statistics was ~25% as large as the increase caused by adding binocular disparity. We propose a model of population encoding in early visual cortex that could feasibly feed relevant depth-from-luminance information forward to higher visual areas.

Acknowledgement: Sony Corporation and NIH grant 2R01EY018875-04A1

54.14, *3:15 pm* **Predicting 3D shape perception from shading and texture flows** Steven A. Cholewiak[1](Steven.Cholewiak@psychol.uni-giessen.de), Benjamin Kunsberg[2], Steven Zucker[2], Roland W. Fleming[1]; [1]Department of Experimental Psychology, University of Giessen, Germany, [2]Program in Applied Mathematics, Yale University, USA

Perceiving 3D shape involves processing and combining different cues, including texture, shading, and specular reflections. We have previously shown that orientation flows produced by the various cues provide fundamentally different information about shape, leading to complementary strengths and weaknesses (see Cholewiak & Fleming, VSS 2013). An important consequence of this is that a given shape may appear different, depending on whether it is shaded or textured, because the different cues reveal different shape features. Here we sought to predict specific regions of interest (ROIs) within shapes where the different cues lead to better or worse shape perception. Since the predictions were derived from the orientation flows, our analysis provides a key test of how and when the visual system uses orientation flows to estimate shape. We used a gauge figure experiment to evaluate shape perception. Cues included Lambertian shading, isotropic 3D texture, both shading and texture, and pseudo-shaded depth maps. Participant performance was compared to a number of image and scene-based perceptual performance predictors. Shape from texture ROI models included theories incorporating the surface's slant and tilt, second-order partial derivatives (i.e., change in tilt direction), and tangential and normal curvatures of isotropic texture orientation. Shape from shading ROI models included image based metrics (e.g., brightness gradient change), anisotropy of the second fundamental form, and surface derivatives. The results confirm that individually texture and shading are not diagnostic of object shape for all locations, but local performance correlates well with ROIs predicted by first and second-order properties of shape. The perceptual ROIs for texture and shading were well predicted via the mathematical models. In regions that were

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ROI for both cues, shading and texture performed complementary functions, suggesting that a common front-end based on orientation flows can predict both strengths and weaknesses of different cues at a local scale.

Acknowledgement: NSF-BMBF Joint Program in Computational Neuroscience (FKZ: 01GQ1111)

54.15, *3:30 pm* **Differential sensitivity to surface curvature polarity in 3D objects is not modulated by stereo disparity** Filipe Cristino[1](f.cristino@bangor.ac.uk), Lina I. Davitt[1], Hannah Rettie[1], Charles Leek[1]; [1]School of Psychology, Bangor University

It has previously been shown that observers are more sensitive to detecting changes in concave relative to convex curvature in the bounding contour of 2D shapes (e.g., Barenholtz et al., Cognition, 2003). Here we examined two related issues: (1) Whether this differential sensitivity to curvature polarity extends to the surfaces of three-dimensional (3D) objects, and (2) whether the detection of surface curvature polarity is modulated by stereo disparity. We created 3D rendered 'asteroid like' stimuli, keeping the silhouette constant but modifying part of the object surface by either introducing, removing, extending or reducing a new concave or convex region. In two separate experiments, we asked participants to discriminate between two sequentially presented 3D shapes under either mono or stereo viewing conditions. The results showed that, analogous to curvature detection in 2D bounding contour, participants are significantly better at discriminating between objects if changes occur in a concave region compared to a convex one. We also found observers to be significantly more accurate at detecting changes when curved regions were introduced or removed in comparison to when these were extended or reduced in magnitude. Surprisingly, we found no viewing condition effect; participants performed very similarly in all conditions when viewing the objects in either 2D or 3D, suggesting that the disparity cue is not used to perform the task. These findings provide further evidence of the functional status of concave regions in 3D shape representation.

Acknowledgement: ESRC/EPSRC grant RES-062-23-2075 awarded to CL

54.16, *3:45 pm* **A Model for Stereopsis and Rivalry Based on Orientation Differences** Hugh R. Wilson[1](hrwilson@yorku.ca); [1]Centre for Vision Research, York University

It has been known for a long time that small orientation differences between gratings presented to the two eyes generate a stereoscopic perception of slant. However, large differences trigger binocular rivalry. A dynamical model will be presented that explains both the stereoscopic percept and rivalry, along with binocular contrast matching data. Key to the model is the presence of two sets of inhibitory neurons: one of which operates between similar orientations to normalize contrast, and a second that functions to suppress very different orientations in the two eyes. The first set of inhibitory neurons also functions as a switch to shut off activity in the latter under appropriate conditions. The model predicts that unequal contrasts in the two monocular images will result in a reduced perception of slant, and experimental results support this. Computations also suggest that rivalry ensues at the point where the orientation difference between the two eyes is greater than that existing in natural images.

Acknowledgement: Natural Science & Engineering Research Council of Canada

54.17, *4:00 pm* **Solving stereo transparency with an extended coarse-to-fine disparity energy model** Zhe Li[1](lizhe.tsinghua@gmail.com), Ning Qian[2]; [1]School of Medicine, Tsinghua University, Beijing, China, [2]Department of Neuroscience, Columbia University Medical Center, New York, USA

Disparity energy model provides a biologically plausible mechanism for computing disparity maps from stereograms (Ohzawa, DeAngelis and Freeman, 1990; Qian, 1994). A coarse-to-fine version of the model (Menz and Freeman, 2003; Chen and Qian, 2004), which progresses from large to small scales and uses both position-shift and phase-shift receptive fields, solves stereo matching problem well for many stimuli, including slanted surfaces and natural images. However, because it decodes only one disparity for each location, this model, unlike our visual system, cannot represent two overlapping, transparent planes at different depths. We have now extended the original coarse-to-fine model to solve the difficult stereo transparency problem in a biologically plausible manner. The first extension is to decode all possible disparities from population responses of disparity energy units, instead of decoding only the most probable one as the original model does. The second extension is to apply multiplicative excitation from cells with larger receptive fields to those with smaller receptive fields to implement coarse-to-fine computation. In the original model, coarse-to-fine computation is realized by selecting the group of cells whose binocular receptive fields have a range of phase shifts but a fixed position shift that equals the disparity estimated from cells with larger receptive fields. The current, extended model also uses both position-shift and phase-shift receptive fields, but sets the strongest excitation between cells of different scales when the post-synaptic cell's position-shift parameter matches the pre-synaptic cell's preferred disparity. This modification not only eliminates the artificial "selection" step in the original model but also enables maintenance of complete population responses. With population responses covering the whole range of possible disparities, the new model can represent two transparent planes at different depths reliably. We have demonstrated the success of the model via computer simulations.

Acknowledgement: Tsinghua University 985 fund

Attention: Neural mechanisms and modeling

Tuesday, May 20, 2:30 - 4:15 pm
Talk Session, Talk Room 2
Moderator: John Serences

54.21, *2:30 pm* **Adaptive gain control during human perceptual choice** Samuel Cheadle[1](sam.cheadle@psy.ox.ac.uk), Valentin Wyart[2], Konstantinos Tsetsos[1], Nicholas Myers[1], Vincent de Gardelle[3], Santiago Herce Castañón[1], Christopher Summerfield[1]; [1]Dept. Experimental Psychology, University of Oxford, Oxford, UK, [2]Dept. Études Cognitives, Ecole Normale Superieure, Paris, France, [3]CNRS UMR 8158, Laboratoire Psychologie de la Perception, 75006 Paris, France

Neural systems adapt to background levels of stimulation. Adaptive gain control has been extensively studied in sensory systems, but overlooked in decision-theoretic models.Here, we describe evidence for adaptive gain control during the serial integration of decision-relevant information, revealed thorough deviations from optimality. In the experiment observers indicated whether the tilts of a series of visual gratings fell closer to the cardinal axes (0° and 90°) or diagonal axes (45° and -45°). Using a regression based analysis we identified two separate biases: Firstly, observers over-weighted evidence that arrived closer in time to the decision (recency bias). Secondly, the impact that each sample wielded over choices depended on its consistency with the previous sample, with more consistent or expected samples wielding the greatest influence over choice.This consistency bias was also visible in the encoding of decision information in pupillometric signals, and in cortical responses measured with functional neuroimaging (fMRI and EEG), whereby the strongest correlation between evidence strength and neurophysiological signal strength occurred for consistent evidence. These data can be accounted for with a new serial sampling model in which the gain of information processing adapts rapidly to reflect the average of the available evidence. Furthermore, this adaptive gain mechanim can be implemented in a biologically plausible population coding model by adjustments to the tuning of neurons coding for expected information. The results are consistent with a dynamic representation of current beliefs that is not reliant on additionally integration stages in which the momentary evidence is evaluated, and is consistent with the rapid influence (<250ms) of prior evidence on future sampling.

54.22, *2:45 pm* **The phase of intrinsic oscillations modulates feature and space-based visual attention** Javier Garcia[1](javiergarcia@ucsd.edu), Kimberly Kaye[1], Dennis Williams[1], Thomas Sprague[2], John Serences[1,2]; [1]Psychology Department, University of California, San Diego, [2]Neuroscience Graduate Program, University of California, San Diego

Selective attention is the mechanism that enables the selection of behaviorally relevant inputs to be prioritized at the expense of irrelevant inputs. Evidence suggests that this process is not static; instead, it ebbs and flows in an oscillatory manner. Here, we investigate oscillatory interactions with feature and space-based attention. Previously, we used steady-state visual evoked potentials (SSVEPs) to extract high temporal resolution information about stimulus orientation based on the spatiotemporal pattern of EEG responses across the scalp (Garcia et al., 2013). In the present study, subjects viewed a high frequency (20Hz) flickering grating (Experiment 1) and checkerboard (Experiment 2) while they search for occasional targets. We reconstructed either the attended feature (E1) or the attended spatial location (E2) using the SSVEP signal across all EEG electrodes. In Experiment 1, the phase of the intrinsic alpha cycle modulates the orientation response profile, such that responses are larger at a trough of the alpha cycle and attenuated at an alpha peak. In Experiment 2, the magnitude of spatially selective responses increases and decreases as a function of both intrinsic theta and alpha phase. Interestingly, modulations within the theta band display an interaction with stimulus type (attended vs ignored), suggesting a key role in the deployment of spatial attention, whereas modulations within the alpha band are more generally related to overall response amplitude. Together, these results suggest that attention modulates the fidelity of population codes for stimulus information in an oscillatory manner that depends upon the types of feature (space or orientation) attended.

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54.23, *3:00 pm* **Neural mechanisms of object-based attention**

Daniel Baldauf[1](baldauf@mit.edu), Robert Desimone[1]; [1]McGovern Institute for Brain Research, MIT

Attention to a location in space is thought to be mediated by feedback to visual cortex from spatially-mapped control structures such as the frontal eye field, but how we attend to objects and features that cannot be separated by location is not understood. We addressed this question with a combination of MEG and fMRI. We presented two temporally and spatially overlapping streams of objects, faces versus houses, and used a frequency-tagging approach to separate responses to attended and unattended stimuli. Attention to faces versus houses enhanced the sensory signals in the fusiform face area (FFA) and parahippocampal place area (PPA), respectively, as well as in a particular portion of the prefrontal cortex, the inferior frontal junction (IFJ); however, the FFA and PPA frequency-tagged sensory signals were advanced in phase by 25ms compared to IFJ, i.e. the sensory transmission time. By contrast, the top-down information for attention to faces and houses was associated with gamma frequency synchronization between the IFJ and the FFA and PPA respectively, and the IFJ led these areas by an equivalent 25ms, in gamma phase, i.e. the feedback transmission time. With these delays, activity in one area would be optimally timed to impact processing in the connected area. DTI tractography confirmed that the IFJ was connected with both FFA and PPA. Thus, the IFJ seems to be a key source of signals for object-based attention, and it modulates the sensory processing of objects at least in part through phase-advanced gamma-frequency synchronization.

54.24, *3:15 pm* **Object attention in moderate precision tasks: Mechanisms of the elaborated template model.**

Barbara Dosher[1](bdosher@uci.edu), Zhong-Lin Lu[2], Songmei Han[3], Shiau-Hua Liu[4]; [1]Cognitive Sciences, University of California, Irvine, CA 92697-5100, [2]Psychology, The Ohio State University, Columbus, OH 43210, [3]Usability Engineering, Apollo Group Inc., Phoenix, AZ 85040, [4]Counseling and Clinical Psychology, National Dong-hwu University, Taiwan

Effects of attention have been widely tested in low precision tasks that discriminate quite different stimuli (i.e., horizontal and vertical pattern orientations), but far less often in high precision tasks that discriminate similar stimuli (i.e., with very similar angles). Without explicitly testing higher precision tasks and an associated observer model, effects of attention on the asymptotes of psychometric functions lack a principled account. Here we show that an elaborated perceptual template model (ePTM; Jeon et al, 2009; Liu et al, 2009) identifies the mechanisms of dual-object attention—deficits in reporting one feature each for two objects compared to two features of one object. Dual object conditions report the orientation of one Gabor object and phase of another; single object conditions report orientation and phase of the same object. Object attention effects were examined in a large data set comprising dual object and single object tests, each with a family of psychometric functions in six different levels of external noise, yielding threshold versus external noise curves for modestly high precision judgments of Gabor orientation and phase. The ePTM accounts for 84 conditions each for phase and orientation judgments (2 object x 6 external noise x 7 Gabor contrast conditions) by a narrowing of the attended template compared to the unattended template—resulting in both asymptotic effects of attention in all conditions and substantial effects across the psychometric function in high external noise associated with external noise filtering. The ePTM, composed of two overlapping templates, nonlinearity, internal multiplicative and additive noise, and decision, provides a principled account of patterns of the effects of attention on the psychometric function sometimes associated with response and contrast gain. The use of higher precision judgments revealed the impact of the narrowing of the attention template in the dimension of judgment on the asymptotes of psychometric functions.

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54.25, *3:30 pm* **External noise distinguishes mechanisms underlying attention gating in visual short-term memory**

Yukai Zhao[1](yukai.zhao@usc.edu), Zhong-Lin Lu[2], Barbara Anne Dosher[3]; [1]Neuroscience Graduate Program, University of Southern California, CA 90089, USA, [2]Laboratory of Brain Processes (LOBES), Department of Psychology, the Ohio State University, Columbus, OH 43210, USA, [3]Memory, Attention and Perception Laboratory (MAPL), Department of Cognitive Sciences and Institute of Mathematical Behavioral Sciences, University of California, Irvine, CA 92697-5100, USA

Attention is essential in selecting task-relevant information to enter capacity-limited visual short-term memory. The Attention Gating Model (AGM, Reeves & Sperling,1986) captures the temporal dynamics of attention shifts and explains a range of attention effects in high item signal to noise conditions (Sperling & Weichselgartner, 1995; Shih & Sperling, 2002). We developed a new model, the attention gating perceptual template model (agPTM), combining the AGM and the perceptual template model (Lu & Dosher, 2008), to account for performance in different stimulus conditions, including low signal contrast, high external noise, unequal item intensity or signal-to-noise ratio. Input stimuli go through contrast-gain, and are then modulated by an attention gate, with internal noise in each stage of processing. The outputs determine the discriminability and memory strength of each item. Two experiments presented a single RSVP stream of 19 letters at fovea @ 10 letters/s. Subjects reported the four earliest letters following a visual cue between the 6th and the 13th letter. Experiment 1 tested six signal contrasts spanning the full range of performance in both zero and high external noise. In experiment 2, all letter contrasts were 0.5 except that two-thirds of the energy of one letter (1, 2, 3, or 4th after the cue) was replaced with external noise by phase-scrambling the same letter. This allowed us to test two potential models of memory strength: proportional to the signal-to-noise ratio or total energy of each item. Data from both experiments were modeled with a single set of parameters. Assuming memory strength proportional to item signal-to-noise ratio provided an excellent account of all the data. In conclusion, a new agPTM accounts for performance in attention switching over a wide range of stimulus conditions. Attention gated memory strength reflects the signal-to-noise ratio instead of total energy of the items in the stimuli.

Acknowledgement: MH081018

54.26, *3:45 pm* **LiFE: Linear Fascicle Evaluation a new technology to study visual connectomes**

Franco Pestilli[1](frk@stanford.edu), Jason Yeatman[1], Ariel Rokem[1], Kendrick Kay[2], Hiromasa Takemura[1], Brian Wandell[1]; [1]Stanford University, [2]Washington University in St. Louis

Diffusion-weighted magnetic resonance imaging and computational tractography are unique methods to measure the white matter in living brains. In the decade since their development, these methods revolutionized our understanding of the importance of the human white-matter for health and disease. Critical to the study of the white matter is the quantification of the confidence in the estimated fascicles and statistical testing of neuroanatomical hypotheses about connectivity. We will present a technology, called LiFE, to perform both validation and statistical inference on living connectomes. This new method improves upon the current state-of-the-art in fundamental ways and can be applied to any type of diffusion data in human and animal brains. We measured diffusion MRI at high spatial (1.5 mm isotropic) and angular resolution (96 diffusion directions). We used constrained spherical deconvolution and probabilistic tractography (Tournier et al., 2012) to generate candidate connectomes. Tractography takes diffusion data as input and estimates white-matter fascicles as output - the candidate connectome. LiFE takes the candidate connectome as input and predicts diffusion data as output. LiFE identifies the fascicles contributing to predicting the diffusion data and eliminates the rest as false connections. We used the technology to identify a major white-matter pathway communicating information between the dorsal and ventral visual streams; the Vertical Occipital Fasciculus (VOF). This pathway is large and its organization establishes that the human ventral and dorsal visual streams communicate substantial information through areas V3A/B and hV4/VO-1. We suggest that the VOF is crucial for transmitting signals between regions that encode object properties including form, identity and color information and regions that map spatial location to action plans. Our results provide novel ways to study the network of white-matter connections in the living brain and important insights on the organization of the visual field maps.

Acknowledgement: NIH, NSF, Japanese Society for the Promotion of science

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54.27, *4:00 pm* **An Information Theory of Vision: why visual search is log-linear (not just linear).** Alejandro Lleras[1](Alejandro.Lleras@gmail.com), Simona Buetti[1]; [1]Department of Psychology, University of Illinois

Traditional models of visual search propose (a)that visual search is driven by similarity such that attentional priority is given to those objects most similar to the target and (b)that attentional efficiency is indexed by the slope of the search function. Here we show evidence that both of these basic tenants of visual search are fundamentally wrong. Our theory (Information Theory of Vision; Lleras, Cronin & Buetti, submitted) proposes that visual search is the product of two sequential and independent stages: (1)an attentional screening stage, where information in the display is processed with the goal of determining the locations most likely to contain the target; and (2)a subsequent scrutiny stage, where those locations are scrutinized. Crucially, screening is resolution limited. It cannot find the target location when items sufficiently similar to the target (candidates) are in the display. However, it can readily discount sufficiently dissimilar items (lures). We show that most of visual search, in fact, happens during (1), not (2), both in traditional laboratory search tasks and in search through real-world scenes. Our theory proposes that the duration of (1) respects Hick's law: it is proportional to the information in the display, when information is measured according to Shannon's uncertainty principle. In four experiments, we present empirical evidence that: (1) is directly proportional to information, producing RT functions that increase logarithmically as a function of the number of items in the display; and (2) attentional scrutiny (the slope) is actually unaffected by candidate-lure dissimilarity. We estimated the parameters of our model based on these four experiments and used them to accurately predict performance (Rsq>0.90) in new experiments containing novel combinations of lures. The data also provide evidence that lures are rejected in sequential, decreasing order of dissimilarity to the target, quickly reducing the uncertainty about locations worthy of precise scrutiny.

Scene perception

Tuesday, May 20, 5:15 - 7:15 pm
Talk Session, Talk Room 1
Moderator: Melissa Vo

55.11, *5:15 pm* **Local Structure Drives Human Scene Categorization: Converging Evidence from Computational Analysis, Behavior, and Neural Decoding** Heeyoung Choo[1](choo.38@osu.edu), Dandan Shen[2], Dirk Walther[1]; [1]Department of Psychology, The Ohio State University, [2]Google

People can categorize scenes accurately and rapidly. Which visual properties do they use to categorize scenes with such efficiency? Here we provide conclusive evidence from computational analysis, behavioral testing, and decoding from neural activity that intact local structure of scenes is essential for human scene categorization. (1) We extracted structural properties of contours (orientation, length, and curvature) and contour junctions (types and angles) from line drawings of natural scenes. Of these properties, orientation contained the most information about scene category that can be exploited computationally. We found, however, that junction properties (requiring precise localization of contours, thus only available locally) generated prediction errors most similar to errors made by humans in a six-alternative forced-choice scene categorization task. (2) To further test their role in scene categorization we selectively perturbed junctions (by randomly shifting contours) and orientation (by randomly rotating the image). Participants categorized rotated scenes more accurately than contour-shifted scenes. More importantly, error patterns of rotated but not contour-shifted scenes correlated with error patterns of intact scenes. (3) How do these manipulations affect the neural representation of scene categories? Using functional magnetic resonance imaging we recorded brain activity of participants passively viewing intact, rotated, and contour-shifted scenes. We could decode viewed scene category from intact and rotated but not from contour-shifted scenes in the parahippocampal place area (PPA), retrosplenial cortex, and the occipital place area. Furthermore, decoding errors in PPA matched behavioral errors if and only if local structure was preserved, i.e., for rotated and intact scenes. We conclude that local structure is essential for scene categorization by humans. Disruption of local structure degrades scene categorization performance and affects category-specific neural activation patterns in PPA. The view that scene perception is chiefly determined by global scene properties needs to be revised in light of these results.

55.12, *5:30 pm* **A simple rapid categorization model accounts for variations in behavioral responses across rapid scene categorization tasks** Thomas Serre[1](thomas_serre@brown.edu), Imri Sofer[1], Sébastien M. Crouzet[2]; [1]Department of Cognitive, Linguistic & Psychological Sciences, Brown University, [2]Institute of Medical Psychology, Charité University Medicine Berlin, Germany

Rapid categorization paradigms, characterized by short presentation times and speeded behavioral responses, highlight both the speed and ease with which our visual system categorizes natural scenes. Existing computational models of perceptual categorization have been developed in the context of simple parameterized stimulus spaces. How these models generalize to natural scenes remains an open question. Here we consider a simple class of categorization models, which assumes that different categorization tasks correspond to different decision boundaries which curve the same perceptual space. We compute a simple measure of discriminability using a rudimentary visual representation (Oliva & Torralba, 2001) and a linear classifier to derive a decision value for individual images. Decision values thus reflect the expected difficulty to categorize individual stimuli in a task-dependent manner. In the first two experiments we validate the model's main assumptions: In experiment 1, we demonstrate that the model predicts variations in accuracy and reaction time at the level of individual images using a natural/man-made categorization task. In experiment 2, we show that the model is consistent with variations in behavioral responses across tasks using published data from different groups (Greene & Oliva, 2009; Loschky & Larson, 2010; Kadar & Ben Shahar, 2012). Next, we show that the model provides a parsimonious explanation for the so-called superordinate advantage whereby superordinate categorization is faster and more accurate than basic categorization (Joubert et al., 2007). In experiment 3, we use the model to sample stimuli to design a reverse experiment, making participants' superordinate categorization slower and less accurate than basic categorization. In experiment 4, we extend the model to reproduce distributions of reaction times and explain previously reported latency effects (Joubert et al., 2007). Overall, our results suggest that a simple model of visual categorization provides a parsimonious explanation for several published results and reported phenomena.

Acknowledgement: This work is supported by NSF early career award (IIS-1252951), ONR (N000141110743) and the Robert J. and Nancy D. Carney Fund for Scientific Innovation. Additional support is provided by the Brown Institute for Brain Sciences (BIBS), the Center for Vision Research (CVR) and the Center for Computation and Visualization (CCV).

55.13, *5:45 pm* **Visual And Semantic Representations Of Scenes** Manoj Kumar Kumar[1,2](mkumar9@illinois.edu), Kara D. Federmeier[1,2,3], Li Fei-Fei[4], Diane M. Beck[1,2,3]; [1]Neuroscience Program, University of Illinois , [2]Beckman Institute, University of Illinois, [3]Department of Psychology, University of Illinois, [4]Department of Computer Science, Stanford University

A long-standing core question that has remained unanswered in cognitive science is: Do different modalities (pictures, words, sounds, smells, tastes and touch) access a common store of semantic information? Although different modalities have been shown to activate a shared network of brain regions, this does not imply a common representation, as the neurons in these regions could process the different modalities in completely different ways. A truer measure of a "common code" across modalities would be a strong similarity of the neural activity evoked by the different modalities. Using multi-voxel pattern analysis (MVPA) we examined the similarity of neural activity across pictures and words. Specifically, we asked if scenes (e.g. a picture of a beach) and related phrases (e.g. "sandy beach") evoke similar patterns of neural activity. In an fMRI experiment, subjects passively viewed blocks of either phrases describing scenes or pictures of scenes, from four different categories: beaches, cities, highways, and mountains. To determine whether the phrases and pictures share a common code, we trained a classifier on one stimulus type (e.g. phrase stimuli) and then tested it on the other stimulus type (e.g. picture stimuli). A whole brain MVPA searchlight revealed multiple brain regions in the occipitotemporal, posterior parietal and frontal cortices that showed transfer from pictures to phrases and from phrases to pictures. This similarity of neural activity patterns across the two input types provides strong evidence of a common semantic code for pictures and words in the brain.

Acknowledgement: This work was funded by a NIH Grant R01 EY019429 (to D.M.B and L.F-F.) and NSF Grant No. 0903622 (to M.K.)

55.14, *6:00 pm* Active visual search boosts memory for objects, but only when making a scene Emilie L. Josephs[1](ejosephs@partners.org), Dejan Draschkow[2], Jeremy M. Wolfe[3], Melissa L.-H. Vo[3]; [1]Brigham and Women's Hospital, [2]Ludwig-Maximilians University, [3]Harvard Medical School, Brigham and Women's Hospital

It seems intuitive that intentionally memorizing objects in scenes would create stronger memory representations than incidental encoding, such as might occur during visual search. Contrary to this intuition, we have shown that observers recalled more objects from photographic scenes following object search than following intentional memorization of the same objects (Draschkow, Vo, & Wolfe, 2013). Does the act of searching itself produce better memorization, or is it necessary to search in realistic scenes? We conducted two experiments in which exemplars of the target objects from the naturalistic scenes were placed on non-scene backgrounds. Object placement was random in Exp1. In Exp 2, placement mimicked real-world positions (e.g. mirror above sink) but did not convey depth information. Displays contained 15 critical objects. Ten were targets in the search or memory tasks. In the search task, Os located target objects – indicated by word cues - as quickly as possible, but were not told to memorize anything. In the memory task, the target object was framed by a red square for 3s immediately after the cue, eliminating the search. Os were instruted to remember as much as possible about the scene, especially the framed objects. Each task was followed by a free recall test, which consisted of drawing as much of the displays as they could remember. Recall performance was evaluated by counting the number of drawn targets. The recall benefit for searched over memorized objects in scenes was eliminated in non-scene displays. Apparently, the simple act of searching is not enough to create a search benefit. While grouping the objects in Exp2 caused better overall object memory, it also failed to produce the recall benefit for searched objects that was observed in naturalistic scenes. Thus we conclude that realistic inter-object relationships are not sufficient to benefit memory for searched objects.

Acknowledgement: This work was supported by ONR N000141010278 to JMW and F32EY022558 to MLV.

55.15, *6:15 pm* Human estimates of object frequency are frequently over-estimated Michelle Greene[1](mrgreene@stanford.edu); [1]Department of Computer Science, Stanford University

Real-world scenes are complex but lawful entities. From our experiences in the world, we know that blenders are more likely to be found in kitchens than forests, that cars are not generally found inside homes, that forks and knives are found near plates, etc. Research over the past 40 years has demonstrated that contextual associations influence object recognition accuracy, change the distribution of eye movements and modulate patterns of brain activations. However, the majority of these studies choose object-scene pairs from intuition because the statistical relationships between objects and scenes had yet to be systematically quantified. How do these intuitive estimations compare to actual object frequencies in the world? Ten observers were asked to list objects that were always, often, sometimes or never in each of 16 scene categories. These estimated object frequencies were then compared to the observed object frequencies in a fully labeled database of 3499 scenes (Greene, 2013). 62% of the objects listed by the observers corresponded to objects observed in the database. Although estimated frequencies were indeed correlated with estimated frequencies (r=0.63), participants systematically overestimated object frequency by 11% on average. Estimated object frequency was significantly greater than observed frequency for all scene categories (p<0.01). Furthermore, the estimation error did not systematically vary with object frequency (r=0.19), suggesting that this overestimation was not solely driven by infrequent objects. Altogether, these results speak to the richness of scene schemata and to the necessity of measuring object frequencies from scene databases because our intuitive estimations are unreliable.

55.16, *6:30 pm* For familiar landmarks, parahippocampal cortex represents place identity, not just perceptual features Steven A. Marchette[1](stevenmarchette@gmail.com), Lindsay K. Vass[1], Jack Ryan[1], Russell A. Epstein[1]; [1]Department of Psychology, University of Pennsylvania

The parahippocampal place area (PPA) responds strongly to environmental stimuli such as landscapes, buildings, and urban scenes. Previous work suggests that the PPA encodes perceptual aspects of these stimuli, such as scene geometry and visual statistics. Whether the PPA also encodes the abstract identity of these items—the "place" as well as the "scene"—is unknown. Here we examined this question by testing whether two very different visual stimuli that correspond to the same place—images of the inside and outside of a building—elicited a common code in the PPA. Participants were scanned with fMRI while they viewed multiple photographs of the interiors and exteriors of ten landmarks from the University of Pennsylvania campus. The participants fell into two groups: Penn students, who were familiar with the buildings and thus knew the correspondences between the interior and exterior images, and Temple University students, who did not have this knowledge. In both subject groups, multivoxel analyses of activity patterns in the PPA revealed that the identity of interiors could be decoded from interior images, and exterior identities from exterior images—an unsurprising result that might be driven by visual or geometric similarities between the images. Notably, however, cross-decoding between interior and exterior images was only significant in Penn students—in Temple students it was at chance. A whole-brain searchlight analysis confirmed that this familiarity-dependent cross-decoding effect was only found in the right PPA. We hypothesize that the PPA constructs abstract "place" representations for familiar landmarks that develop through navigational experience.

55.17, *6:45 pm* Domain specificity in integration of visual information across time Bjorn Hubert-Wallander[1](bjornhw@uw.edu), Geoffrey M. Boynton[1]; [1]Department of Psychology, University of Washington

Perceptual decisions often require integration of information across time. Even a static scene is effectively sampled over time via saccades. Here we consider how humans combine such serially presented information into an overall judgment, and whether the specific type of visual information (e.g., object location/size) affects that integration process. In Experiment 1, subjects viewed a sequence of ten serially presented, small white dots that varied in spatial position. After each trial, they were asked to indicate the perceived center of the sequence via mouse click. A set of ten weights was obtained for each subject that reflects the average influence that each of the ten dots had on the overall judgments. The results clearly show a much larger influence of early dots on the perceived center than later dots (a "primacy" effect), with the first item being weighted on average twice as much as each of the last two items. This primacy effect was replicated across manipulations of stimulus timing and spatial arrangement. In Experiment 2, subjects judged the mean size of eight serially presented discs that varied in radius. Unlike judging mean location, judging mean size across time shows stronger weighting for discs presented later in the sequence – a "recency" effect. We believe these apparently contradictory results can be accounted for by proposing that the dorsal and ventral visual pathways each have a unique method of integrating serially presented information, and that each emphasizes different epochs in the information stream. Specifically, judging mean location of a series may be supported by the dorsal 'where' pathway, while judging mean size may recruit the ventral 'what' pathway. Finally, we show that this novel hypothesis can also unify seemingly contradictory findings in the small number of previous studies that investigated similar effects across a variety of visual domains.

Acknowledgement: BHW is supported by the National Science Foundation Graduate Research Fellowship under Grant No. DGE- 0718124

55.18, *7:00 pm* Can low-level features explain numerosity tuning, or do interference effects reveal how numerosity is computed? Ben Harvey[1](b.m.harvey@uu.nl), Barrie Klein[1], Natalia Petridou[2], Serge Dumoulin[1]; [1]Experimental Psychology, Helmholtz Institute, Utrecht University, Utrecht, 3584 CS, Netherlands, [2]Radiology, Rudolf Magnus Institute of Neuroscience, University Medical Center Utrecht, Utrecht, 3584 CX, Netherlands

Introduction: Numerosity, the set size of a group of items, is processed by association cortex, but certain aspects mirror properties of primary senses (Dehaene, 1997, OUP; Burr and Ross, 2008, Current Biology). The parietal cortex contains numerosity-tuned neurons. We recently demonstrated that numerosity-tuned responses are organized topographically, but that population numerosity preferences vary with stimulus features (Harvey et al., 2013, Science). How is numerosity selectivity related to the low-level visual features from which numerosity is computed? Methods: We used high-field (7T) fMRI and custom-built analyses to capture variations in the time course of numerosity-selective voxels resulting from differences in preferred numerosity and tuning width, following a population receptive field (pRF) design (Dumoulin and Wandell, 2008, Neuroimage). Several control conditions were tested to check that low-level stimulus features that co-vary with numerosity (such as pattern edge length, pattern surface area, pattern density, and individual item size) did not underlie response selectivity. We quantify low-level features in these stimuli to investigate their effects on numerosity selectivity. Results: Numerosity explained population responses far better than any low-level feature. However, numerosity preferences can be affected by stimulus features in some subjects when features vary incongruently with numerosity. These interference effects are found particularly when display luminance contrast and item size decrease strongly when numerosity increases. Even in this situation, populations remain tuned to numerosity and the topographic representation of

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numerosity remains in the same direction. Conclusions: Numerosity, not low-level features, is the primary stimulus dimension underlying numerosity-selective responses and cortical organization. However, numerosity must be derived from early visual feature selectivity. Interactions between numerosity tuning and stimulus features suggest how numerosity may be computed (Dakin et al, 2011, PNAS). Alternatively, effects of both numerosity and object size on population tuning suggest that these different magnitudes may be processed together (Walsh, 2003, TICS).

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Multisensory processing

Tuesday, May 20, 5:15 - 7:15 pm
Talk Session, Talk Room 2
Moderator: Pascal Mamassian

55.21, *5:15 pm* **Cue combination with a new sensory signal: multisensory processing in blind patients with a retinal prosthesis** Sara Garcia[1](sara.garcia.12@ucl.ac.uk), Karin Petrini[1], Lyndon da Cruz[2], Gary Rubin[1], Marko Nardini[3]; [1]Visual Neuroscience, Institute of Ophthalmology, University College London, [2]Vitreoretinal Service, Moorfields Eye Hospital NHS Foundation Trust, London, [3]Department of Psychology, Durham University and Visual Neuroscience, Institute of Ophthalmology, University College London

Prolonged visual deprivation can result in enhanced perception by non-visual modalities, reflecting neural pathway re-organisation (e.g. Collignon, Lassonde, Lepore et al., 2007). However, it is not yet clear whether further re-organisation is possible when visual information is partially restored. Here we ask whether patients implanted with retinal prostheses, which partially restore vision, can combine this new visual signal with non-visual information for faster or more accurate perception. Five participants (4 retinitis pigmentosa, 1 choroideremia; aged 49-76yrs) implanted with Second Sight's Argus II retinal prostheses in 2008-09, took part. They completed three tasks: a visual-haptic size judgment task, in which they compared two balls using vision, touch, or both; a visual-auditory detection task, in which they made speeded responses to flash, beep, or flash-beep stimuli; and a navigation task, in which they used visual and/or self-motion information to reproduce a path or complete a triangle. When discriminating ball sizes, no participants gained from added visual information, as haptic estimates alone were highly reliable. Two participants, however, showed multisensory speed gains exceeding those expected by probability summation on the audio-visual task. Of four tested so far on navigation, all showed less accurate performance with visual information on the path reproduction task, indicating that they used vision but that it was detrimental. These results suggest that after the retinal implant some sensory re-organisation is possible, specifically for temporal judgments and simple audiovisual tasks. However, these patients' prosthetic vision is not reliable for more complex spatial judgments. This likely reflects difficulties in interpreting spatial information due to differences between prosthetic and native vision. However, training may enable patients to learn the statistical relationship between the new visual and non-visual signals.

Acknowledgement: NIHR BRC at Moorfields Eye Hospital UCL Institute of Ophthalmology Second Sight Medical Products

55.22, *5:30 pm* **Asymmetrical medial geniculate body volume in people with one eye** Stefania S. Moro[1,2,4](smoro@yorku.ca), Krista R. Kelly[1,2,4], Larissa McKetton[2,3], Jennifer K.E. Steeves[1,2,4]; [1]Department of Psychology, York University, Toronto, Canada, [2]Centre for Vision Research, York University, Toronto, Canada, [3]Department of Biology, York University, Toronto, Canada, [4]The Hospital for Sick Children, Toronto, Canada

Introduction. We have previously shown that people who have lost one eye early in life have enhanced sound localization (Hoover et al., 2011) and lack visual dominance (Moro & Steeves, 2011) compared to binocular and eye-patched viewing controls. People with one eye integrate auditory and visual information optimally, similar to controls, despite taking longer to localize unimodal visual stimuli (Moro, Harris & Steeves, 2013). Structurally, people with one eye have decreased lateral geniculate nuclei volume (LGN; thalamic visual relay station). However, this decrease is less severe in the LGN contralateral to the remaining eye, indicating altered structural development (Kelly, et al., 2013). The medial geniculate body (MGB; thalamic auditory relay station) plays a central role in auditory processing with both efferent and afferent tracts to primary auditory cortex (Schönwiesner, et al., 2007). Given the existing audiovisual processing differences and LGN changes in people with one eye, we investigated whether structural MGB changes are also present. Methods. MGB volume of adults who had undergone early unilateral eye enucleation was compared to binocularly intact controls. A series of 40 high-resolution proton density-weighted images were acquired with a 3T MRI scanner. Each series of scans were co-registered and averaged. Raters manually identified and traced MGB regions of interest in each participant. Results. People with one eye had a significant increase in MGB volume in the left compared to the right hemisphere independent of eye of enucleation. Controls did not exhibit this asymmetry. Conclusions. The volume asymmetry in the MGB in people with one eye may represent increased interaction between the left MGB and primary auditory cortex. This interaction could contribute to increased auditory attention, auditory spatial processing and other left hemisphere-dominant processing, including language. This asymmetry may reflect compensation for the loss of one half of visual inputs early in life.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada, Canada Foundation for Innovation, Toronto Rehabilitation Institute

55.23, *5:45 pm* **Electrocorticographic (ECoG) recordings demonstrate that peripherally presented sounds activate extrastriate visual cortex** David Brang[1,2](dbrang@gmail.com), Vernon L. Towle[2], Satoru Suzuki[1], Zhongtian Dai[2], Steven A. Hillyard[3], Michael H. Kohrman[2], James X. Tao[2], Marcia Grabowecky[1]; [1]Psychology, Northwestern University, [2]Neurology, University of Chicago, [3]Neurosciences, University of CA, San Diego

Multisensory interactions comprise a class of processes through which our senses communicate to facilitate perception and behavior. Although much research has focused on the dominance of vision over audition, under some conditions, sounds have been demonstrated to alter visual perception as well. For example, during the double flash illusion, the auditory system's high temporal resolution can override visual cues, such as when a single visual flash paired with two auditory beeps results in the illusory experience of two distinct visual flashes. Additionally, the auditory system's high sensitivity to events occurring outside the central vision field allows fast and accurate localization of auditory-visual targets, which in turn enhances subsequent visual discrimination of targets. Here we examined the cortical networks underlying auditory influences on visual perception using subdural electrocorticographic (ECoG) measures of local field potentials in patients with epilepsy as they performed a double flash illusion task and an auditory detection task. When participants experienced auditory-induced double flashes, we observed rapid communication between primary auditory areas, extrastriate visual regions, and the angular gyrus, suggesting that each of these areas is involved in the generation of the illusory second flash. As these data suggest that activity in visual areas is evoked by simple sounds, we tested this hypothesis in the same participants using an auditory detection paradigm. Participants detected centrally presented 1 kHz tones and ignored laterally presented noise bursts. Consistent with results from the double-flash paradigm, visual activity was evoked by sounds between 80 and 250 ms post stimulus onset, following primary auditory cortex activity by 20 ms, and this auditory-evoked visual activity was greater in the contralateral hemisphere. These results suggest the existence of a fast and dynamic pathway between auditory and visual cortices, allowing auditory signals to activate visual cortex in order to facilitate the detection of non-foveal visual stimuli.

Acknowledgement: NIH Grant R01 EY021184 and NINDS Grant 2T32NS047987

55.24, *6:00 pm* **Enhanced cortical representation of auditory frequency as a result of early blindness** Elizabeth Huber[1], Jessica Thomas[1], Ione Fine[1]; [1]Department of Psychology, University of Washington

A fundamental ability found to be enhanced by early blindness is frequency discrimination; however, the neural basis of this enhancement is unclear. Responses to a variety of auditory stimuli have been found throughout occipital cortex, but clear evidence for frequency tuning has not been reported. In auditory cortex, attenuated responses to pure tones have been found in early blind and anophthalmic individuals (Stevens and Weaver, 2009; Watkins et al., 2013). Here, we measured responses to pure tones in 5 early-blind and 5 age-matched sighted subjects to assess group differences in the organization of auditory frequency representations within occipital and auditory cortex. Methods: Stimuli consisted of pure tones ranging from 88 to 8000 Hz, which were presented in partially randomized order while subjects performed a 1-back frequency matching task. Data were analyzed using an adaptation of the population receptive field technique (Dumoulin and Wandell, 2008). We modeled the aggregate receptive field underlying each voxel's response as a one-dimensional Gaussian function of frequency, with a center and standard deviation that reflect preferred frequency and tuning bandwidth, respectively. Results: Within auditory cortex, we could

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reliably measure individual tonotopic maps in both subject groups, and we saw no evidence for an attenuation of responses. Relative to controls, early-blind subjects showed an enhanced representation of low to middle frequencies (<4 kHz) and narrower tuning bandwidths. In occipital cortex, blind but not sighted subjects showed evidence of auditory frequency tuning. Frequency tuned voxels in occipital cortex favored the mid-frequency range (1-8 kHz) and had narrower bandwidths then those found in auditory cortex. Conclusions: Early blindness results in an increased cortical representation of behaviorally relevant frequencies within both auditory and occipital cortex. Future work will examine how responses in these cortical areas relate to frequency discrimination performance in individual subjects.

Acknowledgement: NEI EY-014645

55.25, *6:15 pm* **Predicting linear and nonlinear interactions in the temporal profile of the multisensory response**

Ryan Miller[1](ryamille@wakehealth.edu), Barry Stein[1], Benjamin Rowland[1]; [1]Neurobiology and Anatomy, Wake Forest School of Medicine

Data from a variety of experimental preparations reveal that when a multisensory neuron is unable to integrate a pair of cross-modal inputs, it "defaults" to a response less than or equal to its largest unisensory component response -- not a sum of those responses (i.e., the additive prediction). Furthermore, when the neuron does integrate its cross-modal inputs, its response often exceeds the sum of its component responses. Additive predictions prove to be consistently biased in predicting a multisensory response in several ways: (a) response begins earlier than predicted, (b) early portions are stronger than predicted, and (c) later portions are weaker than predicted. Thus, additive models fail to capture the dynamic features of multisensory integration and underrate its ability to enhance incoming information. Here we illustrate a simple, biologically-inspired model based on input current summation rather than the more familiar response summation. Unisensory responses for a given neuron are transformed into input currents which are summed and combined with an inhibitory factor and then transformed back into a predicted response. Using a minimal set of parameters (i.e., membrane time constant, noise, and an inhibitory scaling factor), this model accurately matches the entire temporal profile of the multisensory response for nearly all neurons. Even when all model parameters are fixed, the model's predictive power far exceeds that of the additive model. This is the first model using the actual unisensory responses as inputs that can accurately predict the temporal evolution of actual multisensory responses. Supported by NIH grants EY016716 and NS036916

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55.26, *6:30 pm* **Cross-modal confidence judgements**

Pascal Mamassian[1](pascal.mamassian@ens.fr), David Alais[2]; [1]Laboratoire des Systèmes Perceptifs, CNRS & Ecole Normale Supérieure, Paris, France, [2]School of Psychology, University of Sydney, Sydney, Australia

An event defined by two sensory modalities has better precision than either modality alone (Ernst & Banks, 2002, Nature; Alais & Burr, 2004, Curr Bio). Is the original precision of one modality still available once bimodal combination occurs? We used a perceptual confidence judgement to address this issue. Perceptual confidence (the subjective sense of the accuracy of a perceptual decision) depends primarily on the encoded stimulus precision (higher confidence for higher precision). We reasoned that if participants no longer had access to visual precision in an audio-visual stimulus their visual judgments would be over-confident when auditory precision was high and under-confident when auditory precision was low. Stimuli consisted of flickering grey bars that were initially slightly brighter on the left side and then slightly brighter on the right side. Participants indicated on which side the bright bars appeared for longer (duration bisection task). While performing this visual task, they wore headphones and heard a sound that started in the left ear and finished in the right. Even though instructed to ignore the sound, the transition duration of the sound, short or long, increased or decreased their sensitivity on the visual task. Participants then made a confidence choice (Barthelmé & Mamassian, 2010, PNAS) between two stimuli with identical visual properties but differing in auditory precision. We found that participants could reliably make confidence judgements, and thus exhibited meta-perception. However, participants also presented a bias to be more confident when auditory precision was high than when it was low. Our results show that visual and auditory signals were combined and improved the temporal judgement, and that participants were fooled by the combined bimodal percept when asked to perform a unimodal confidence judgement.

55.27, *6:45 pm* **Audio-visual delay as a new cue to visual distance**

Philip Jaekl[1](pjaekl@gmail.com), Duje Tadin[1,2]; [1]Center for Visual Science & Dept. of Brain and Cognitive Sciences, University of Rochester, Rochester, NY, USA 14627, [2]Department of Ophthalmology, University of Rochester School of Medicine, Rochester, NY, USA 14627

For audiovisual events, sound arrives with a delay relative to light. This delay varies linearly with the event distance. We sought to determine if this ubiquitous audiovisual asynchrony can be exploited as a multisensory cue to object distance. Specifically, we hypothesized that events with greater audiovisual delays will be perceived as being further. To test this hypothesis we presented visual stimuli paired with leading and lagging sound onsets. In an adjustment task, participants (N = 5) controlled the disparities of dots within two random dot clusters, presented one at the time on the left and right of the display. Participants adjusted the disparities such that increases on one side corresponded with decreases on the other. When they perceived the clusters to have the same distance, the relative disparity was recorded as a response variable. For each stimulus, one dot cluster was paired with a sound lead, while the other was paired with an equal sound lag. Sound asynchronies were between 0 and 100 ms in 20 ms increments. The results showed that for audiovisual asynchronies greater than 20 ms, participants had a significant bias of perceiving dot clouds that were paired with a sound delay as being more distant. Evidently, sound delays can be used as a non-metric cue to visual distance. These findings reveal a new role of multisensory audiovisual cues in depth perception, a function commonly regarded as a unimodal, visual process.

55.28, *7:00 pm* **What colours a letter? The deep learned structure of synaesthesia in two linguistic groups**

Marcus R Watson[1](mwatson@cfri.ca), Kathleen A Akins[2], Jan Chromý[3], John Alderete[4], Martin Hahn[2], James T Enns[5]; [1]Ophthalmology & Vision Sciences, The University of British Columbia, [2]Department of Philosophy, Simon Fraser University, [3]Institute of Czech Language and Theory of Communication, Charles University, [4]Department of Linguistics, Simon Fraser University, [5]Department of Psychology, The University of British Columbia

The development of grapheme-colour synaesthesia is a slow process, in which children gradually develop a consistent set of colours associated with each letter of the alphabet, beginning before age 6 and continuing until at least age 12 (Simner & Bain, 2013). During this time, a wide range of factors influence the specific colour associated with a given letter, factors that recent research is beginning to tease apart. These include semantic associations with letters, their order in the alphabet, phonological characteristics, shape, and frequency of use (e.g. Simner et al., 2005; Asano & Yokosawa, 2013; Watson, Akins & Enns, 2012). Here we directly compare these influences and several never previously-described in two distinct populations of synaesthetes (native Czech and English speakers). We find that while some factors (e.g. letter shape and alphabetical order) have similar effects in the two groups, other factors are particular to each language. For instance, the regular relationship between phonemes and graphemes in Czech enables the phonological similarity of letters to influence their colours, unlike in English, and Czech has several diacritical marks that influence the colour of their letters in different ways. The overall picture that emerges is one of complex interacting influences competing with each other over the course of synaesthetic development, leading to the apparently idiosyncratic sets of colours of adult synaesthetes.

Acknowledgement: SSHRC, NSERC, McDonnell Foundation

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Tuesday Afternoon Posters

Temporal processing

Tuesday, May 20, 2:45 - 6:45 pm
Poster Session, Jacaranda Hall

56.301 Dissecting the neural network of duration perception with fMRI

Mingbo Cai[1](mcai@cpu.bcm.edu), David Eagleman[1,2]; [1]Department of Neuroscience, Baylor College of Medicine, [2]Menninger Department of Psychiatry & Behavioral Sciences, Baylor College of Medicine

Traditional neural models of time perception often assume a dedicated amodal brain system for encoding time. In contrast, some recent models suggest that time may be intrinsically encoded in sensory cortices that also code for other aspects of stimuli. The role of the sensory cortices in time perception is often overlooked in functional magnetic resonance imaging (fMRI) studies. To date, few studies have attempted to decode temporal features of sensory stimuli with fMRI. To this end, we examined both intrinsic and dedicated models of time perception by evaluating the tuning properties of sensory and other brain regions given different stimulus durations. We recorded whole brain fMRI signals while participants made bisection judgments of the duration of visual stimuli in the sub-second range. The stimuli were flashed Gabor patterns drifting at different speeds—a manipulation previously shown to modulate their subjective duration. For every voxel, we used training data to estimate the hemodynamic response function and tuning curve to different physical durations. The fMRI response monotonically increases with the stimulus duration mainly in the visual cortices. U-shaped or inverse U-shaped tuning curves are observed in various regions including anterior insula, paracingulate cortex, putamen, anterior cingulate cortex and distributed frontal and parietal regions. For each participant, we then used Bayesian decoder to decode the subjective duration of testing data with 6-fold cross-validation using voxels whose responses were modulated by stimulus durations. Decoded duration correlated well with physical duration when the decoding employed voxels from occipital, temporal or parietal cortex. However, the correlation weakened when decoding from voxels in the frontal cortex. Finally, the correlation disappears when decoding from voxels in basal ganglia or insula, suggesting that these latter regions may encode task difficulty more than duration in particular. In summary, the data suggest both sensory and frontal regions encode subjective duration.

56.302 Endogenous alpha oscillations modulate the perception of causality

Andre Mascioli Cravo[1](andre.cravo@ufabc.edu.br), Karin Moreira Santos[1], Marcelo Bussotti Reyes[1], Marcelo Salvador Caetano[1], Peter Maurice Erna Claessens[1]; [1]Center for Mathematics, Computation and Cognition, Federal University of ABC (UFABC), Santo André, Brazil

The perception of causality is essential to help us understand how two events relate to each other. Central to causality is temporal contiguity: estimates of causality decrease as the interval between events increases, and for intervals longer than approximately 150 ms the events appear independent. It has been suggested that this effect might be due to perception relying on discrete processing. Previous work has shown that alpha oscillations (~10Hz) can modulate whether two sequential stimuli are perceived as sequential or simultaneous. However, whether a similar mechanism may modulate the perception of causality remains unknown. Here, we investigated whether the phase of ongoing alpha oscillations modulated the perception of causality. We used the classic launching effect proposed by Michotte with concurrent recording of EEG signal. In each trial a disk moved towards the center of the screen where it touched a central disk. After a certain delay the central disk began moving away. Observers (n=17) had to judge whether the first disk caused the movement of the second. The delay at each trial was chosen via a staircase procedure so that the majority of trials were around the point of maximum uncertainty for that participant. The point of subjective causality (PSC - the delay where participants had maximum uncertainty whether the events were causal) was of 123 ms ± 13:45 (mean ± sem). We found that fronto-central alpha phase at the moment in which the second disk started moving significantly modulated the PSC. Moreover, we found that alpha phase was concentrated around different angles in trials where participants perceived events as causal or not. We conclude that alpha phase plays a key role in modulating the sense of causality adding support to the notion that perception is discrete.

56.303 Pupillometry reveals role for norepinephrine in the isolation effect

Taylor R. Hayes[1](hayes.335@osu.edu), Per B. Sederberg[1], Brian M. Siefke[1], Alexander A. Petrov[1]; [1]The Ohio State University

In a rich, ever-evolving sensory environment taking note of incongruent events can be a powerful tool. Emerging evidence from animal electrophysiology and computational modeling suggests that norepinephrine may play a key role in how our brains process this type of unexpected uncertainty (Yu & Dayan, 2003). The locus coeruleus (LC) serves as the primary source of norepinephrine in the brain and LC activity is strongly correlated with the pupillary response (Samuels & Szabadi, 2008). Therefore, we used the pupillary response as a non-invasive proxy to assess fluctuations in LC activity during periods of unexpected uncertainty within an isolation effect paradigm. Twenty participants completed 12 blocks of an isolation effect task consisting of study, distraction, and test phases. During study participants viewed a series of 32 words presented on a static background context that would occasionally oscillate between either circles or stars. Participants then performed a math distractor task prior to being tested on each of the 32 studied items. Each test item was a studied word presented on a neutral gray background and participants were asked to indicate whether the word appeared on circles or stars during study. All experimental images were isoluminant and presented under consistent ambient lighting. Pupil diameter was measured continuously using an Eyelink 1000 eye tracker at a sampling rate of 500 Hz. A significant isolation effect was observed as background accuracy was significantly higher for words that occurred when the background context changed than no-change trials at test. More importantly, we observed significantly larger phasic pupillary responses on background change trials relative to no-change trials during study, suggesting a boost in LC/NE activity during these periods. These findings are consistent with the hypothesis that norepinephrine plays an important role in signaling periods of unexpected uncertainty in our sensory environment.

Acknowledgement: Supported by the National Eye Institute

56.304 Dissociating temporal and spatial integration windows: the case of Vernier Fusion

Jan Drewes[1](mail@jandrewes.de), David Melcher[1]; [1]Center for Mind/Brain Sciences (CIMeC), Trento University, Rovereto, Italy

The visual system constructs a percept of the world across multiple spatial and temporal scales. This raises the question of whether different scales involve separate integration mechanisms and whether spatial and temporal factors are linked via spatio-temporal reference frames. We investigated this using Vernier Fusion, a phenomenon in which the features of two Vernier stimuli presented in close spatio-temporal proximity are fused into a single percept. With increasing spatial offset, perception changes dramatically from a single percept into apparent motion and later, at larger offsets, into two separately perceived stimuli (Scharnowski et al., 2007). We tested the link between spatial and temporal integration in a study with 21 subjects, consisting of two successive Vernier stimuli presented at varying spatial (0.5-3′) and temporal (0-200ms) offsets. The second Vernier either had the same or the opposite offset as the first. We found that the type of percept depended not only on spatial offset, as reported previously, but interacted with the temporal parameter as well. At temporal separations around 30-40ms the majority of trials were perceived as motion, while above 70ms two separate stimuli were reported. The dominance of the second Vernier varied systematically with temporal offset, peaking around 40ms ISI. Same-offset conditions showed increasing amounts of perceived separation at large ISIs, but little dependence on spatial offset. As subjects did not always completely fuse stimuli, we separated trials by reported percept (fusion, motion, separation). We found systematic indications of spatial fusion even on trials in which subjects perceived temporal segregation. These findings imply that spatial integration/fusion may occur even when the stimuli are perceived as temporally separate entities, suggesting that the mechanisms responsible for temporal segregation and spatial integration may not be mutually exclusive.

Acknowledgement: The research was supported by a European Research Council (ERC) grant (grant agreement no. 313658)

56.305 **The Broca-Sulzer effect contributes to visual acuity** Hector Rieiro[1,2](hrieiro@neuralcorrelate.com), Francisco Costela[1,3], Oier Dominguez Lopez De Lacalle[1,4], Susana Martinez-Conde[1], Stephen Macknik[1]; [1]Barrow Neurological Institute, Phoenix,AZ, [2]Universidade de Vigo, Vigo, Spain, [3]Arizona State University, Tempe, AZ, [4]Euskal Herriko Unibertsitatea, Bilbao, Spain

Our previous research revealed that contrast sensitivity exhibited a peak as a function of stimulus duration between 50-100 ms, once all known forms of criterion were controlled. Temporal contrast gain thus follows the Broca-Sulzer Effect (BSE) rather than Bloch's Law (BL). We further showed that the BSE could be exploited to reap energy savings in the design of light emitting devices. Nevertheless, the benefits of this perceptual enhancement have not been characterized. Previous studies of visual acuity have shown that performance improves as a function of both contrast and duration, but the duration range that shows this improvement (up to 400 ms) is bigger than the temporal window relevant to the BSE. We hypothesize that stimulus duration contributes to performance in visual acuity tasks in two separate ways: first, longer durations allow the brain to acquire more information about the visual scene; and second, certain durations affect perceived contrast and can therefore improve or worsen performance. For the durations where the BSE holds, these two effects both contribute, in unknown relative amounts. To determine the contribution of the BSE to visual acuity, we used a vernier task in which a pair of vertically oriented and aligned bars flickered with varied duty-cycles for a total duration of 600 ms. Every cycle of flicker had a constant off-time of 16 ms whereas the on-time varied between 17-500 ms, as in our previous study. The subjects' task was to determine if the bottom bar was shifted towards the left or right compared to the top bar. We found that subjects performed better for stimulus on-durations around 100 ms, matching our previous finding that BSE drives an increase in perceived contrast. This result suggests that lighting and display systems can be optimized in a way that improve human performance in tasks such as reading.

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56.306 **Simple duration detectors for encoding event time** Edward Rowland[1](edward.rowland.2009@live.rhul.ac.uk), Johannes Zanker[1], Szonya Durant[1]; [1]Psychology dept. Royal Holloway, Univ. London

Humans can readily distinguish durations of sensory events. However, in contrast to many other basic properties of visual stimuli, such as motion, colour, orientation etc., little is known about the neural encoding of time. Here we present a simple model for encoding the duration of a visual stimulus, using a low pass filter approximating the temporal response of sensory neurons and a step-function nonlinearity (threshold gated output). The time constant (τ) of the low-pass filter determines its response gradient to an input and thus determines the duration between the signal onset and the time at which the threshold is reached and the triggering of an output response. A population of such duration detectors with a range of time constants and fixed thresholds can encode the duration of an input signal in the form of a labelled line set, where the time constant of the most recent detector to reach threshold indicates duration of the signal. This population encodes an on-going estimate of duration since the stimulus onset as well as the final duration at stimulus offset. This mechanism has properties reflecting Weber's law and shows a reduction in its duration estimate when a detector sub-population is reduced in sensitivity (representing adaptation), which corresponds to perceptual effects reported in the literature (Johnston, Arnold, & Nishida, 2006). Although amplitude and frequency of the input signal do not affect duration measures, duration measures in the simplest model increase proportionally with mean input signal intensity. Consequently, we use divisive normalization to keep the mean input signal intensity constant, whilst preserving the signal waveform shape. This work demonstrates that a very basic model, based on the simple temporal response properties of sensory neurons, is capable of encoding an explicit measure of duration and of modelling related psychophysical phenomena.

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56.307 **A role for local mechanisms in perceived duration of brief visual events** Lee Beattie[1](lbeattie15@qub.ac.uk), William Curran[1]; [1]School of Psychology, Queen's University Belfast

Spatially localized duration compression of a briefly presented moving stimulus following adaptation in the same location is taken as evidence for modality-specific neural timing mechanisms. While it is likely that they persist to the cortical level of motion processing, there is on-going debate about where in the cortical motion pathway these mechanisms are located. The following experiments explore the contributions of local and global motion mechanisms to duration perception. In both experiments observers adapted to a unidirectional random dot stimulus (diameter 6.3 deg) presented 5 deg to one side of fixation, and then judged the duration of a 600ms test stimulus (same location) relative to a comparison stimulus on the opposite side of fixation. Presentation order of test and comparison was randomised. Experiment 1 measured duration compression of the test stimulus as a function of adaptor speed. The results revealed that duration compression is speed tuned, and that this speed tuning is well described by a log-Gaussian function. Given that a mixed-speed stimulus appears to move at its mean component speed (Watamaniuk & Duchon, 1992), we can use the speed-tuning data from experiment 1 to test the predictions of local and global models of duration compression. In experiment 2 the adaptor stimulus of Experiment 1 was replaced with a mixed-speed adaptor, with each dot assigned a fixed speed drawn from a speed range (0.75 – 5.25 deg/s) centered on 3 deg/s. Duration compression was measured as a function of the adaptor's 'speed notch' – where speed notch refers to the removal of a central band of speeds from the speed range. As speed notch increases predicted duration compression based on the adaptor's mean local speed and global speed diverges. The results were consistent with a local-mean model, demonstrating the involvement of local mechanisms in duration perception of brief visual events.

56.308 **Local and global mechanisms mediate perceived duration of brief visual events** William Curran[1](w.curran@qub.ac.uk), Christopher P. Benton[2], Julie M. Harris[3], Paul B. Hibbard[4], Lee Beattie[1]; [1]School of Psychology, Queen's University Belfast, [2]School of Experimental Psychology, University of Bristol, [3]School of Psychology and Neuroscience, University of St Andrews, [4]Department of Psychology, University of Essex

Adapting to a spatially localized drifting dot stimulus results in the duration of a subsequent stimulus in the same location being underestimated. This duration compression effect is direction contingent (Curran & Benton, 2012), and likely driven by adaptation of cortical timing mechanisms. What is unclear is whether the adapted mechanisms are at the local or global motion processing level. Our experiments address this question. Experiment 1 measured perceived duration while manipulating the adaptor's motion coherence (0-100%). The adaptor and test stimuli were centered 5 deg to one side of fixation, and the comparison was centered 5 deg to the opposite side. Following adaptation, observers judged whether the comparison stimulus had a longer or shorter duration than the 600ms test stimulus. Presentation order of test and comparison was randomised. Our results show a linear relationship between adaptor coherence and duration compression magnitude. Experiment 2 repeated the coherence experiment while keeping adaptor global speed fixed. The results reveal that, although duration compression persisted, motion coherence level did not influence duration compression magnitude. This suggests that the duration compression magnitude in experiment 1 was driven by adaptor speed, not adaptor coherence; although it is not clear whether the determining factor was the adaptor's local or global speed. Experiment 3 used multiple-Gabor stimuli to investigate the role of local and global mechanisms. The global direction was identical for the adaptor and test stimuli; however in one condition the test pattern of Gabor orientations (hence directions) was identical to the adaptor, and in the second condition each adaptor Gabor element was replaced with its orthogonal orientation in the test stimulus. Duration compression was found for both conditions, demonstrating that global motion mechanisms are involved in sub-second event timing. However, compression magnitude was reduced in the 'orthogonal' condition – suggesting that local mechanisms also play a role.

56.309 **Direction-contingent duration compression is retinotopic** Kevin G Latimer[1](klatimer01@qub.ac.uk), William Curran[1], Christopher P Benton[2]; [1]School of Psychology, Queen's University Belfast, Belfast, BT7 1NN, UK, [2]Department of Experimental Psychology, University of Bristol, 12a Priory Road, Bristol BS8 1TU, UK

Previous research has shown that prior adaptation to a spatially circumscribed oscillating grating results in the duration of a subsequent stimulus presented within the adapted region being underestimated (Johnston et al, 2006; Burr et al, 2007). Recent work using unidirectional stimuli has shown direction-contingent duration compression, which suggests that the underlying adapted mechanisms are cortical in origin (Curran & Benton, 2012). However there is still some disagreement regarding whether adaptation-induced duration compression is retinotopic or spatiotopic. We addressed this question by having participants adapt to a unidirectional (upwards) random dot kinematogram, and then measuring perceived duration of a 600ms test dot pattern located in either the same retinotopic or the same

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spatiotopic location. The adaptor stimulus (6.3 deg diameter) was centered 4.2 deg and 3.5 deg to the right and above fixation, respectively. Initial adaptation lasted 30s, with subsequent 'top up' adaptor stimuli being presented for 5s. Prior to each test phase the fixation spot was shifted 7.6 deg to the right. In the 'retinotopic' condition the test and adaptor retinal coordinates were identical, and in the spatiotopic condition the test and adaptor spatial coordinates were identical. The test stimulus's motion direction was either identical or opposite to the adaptor. The comparison stimulus was centered 4.2 deg and 3.5 deg to the right and below fixation, respectively, and moved in the opposite direction to the test stimulus. Presentation order of the test and comparison stimuli was randomised from trial to trial. While significant direction-contingent duration compression was observed when the adaptor and test stimuli appeared in the same retinotopic location, we found no evidence for spatiotopic duration compression. Our finding demonstrates the involvement of retinotopic-tuned, but not spatiotopic-tuned, cortical mechanisms in the timing of subsecond visual events.

56.310 **Time compressions for dynamic tests following 1st and 2nd order motion adaptation** James Retell[1](j.retell@uq.edu.au), Alan Johnston[2], Derek Arnold[1]; [1]School of Psychology, The University of Queensland, [2]Cognitive, Perceptual & Brain Sciences, University College London

Adaptation to high temporal frequencies can induce a localised reduction in the apparent duration of dynamic tests (Johnston et al., 2006). This effect is dissociable from apparent speed changes (Ayhan et al., 2009), and the specificity of the effect for high temporal frequency adaptation, coupled with its insensitivity to stimulus orientation, suggests a causal locus at an early (pre-cortical) magnocellular stage of analysis (Johnston et al., 2006). The absence of adaptation-induced time compression for isoluminant tests supports this claim (Ayhan et al., 2009). Here we further examined the determinants of adaptation-induced time compression by investigating interactions between 1st-order luminance defined and 2nd- order luminance-contrast defined motion signals. We found that adaptation to an 8Hz first order stimulus markedly reduced the apparent durations of 1st and 2nd order 4Hz tests, whereas adaptation to a 2Hz 1st order signal had little impact on either test type. In contrast, adaptation to 8Hz 2nd order motion shortened the perceived duration of 4Hz 1st and 2nd order tests, but adaptation to a 2Hz 2nd order signal had a selective effect on 4Hz 2nd order tests, with little impact on 4Hz 1st order tests. We believe the efficacy of both 1st order luminance and 2nd order luminance-contrast adaptation further implicates an early magnocellular locus as the critical site for time-compression adaptation.

56.311 **Perceived distance and size interact to alter the perception of time** Martin Wiener[1](mwiener@gmu.edu), James Thompson[1]; [1]Department of Psychology, George Mason University

The perception of time is influenced by a variety of non-temporal factors. Previous studies have suggested that time may be altered by relational differences in size, numerical quantity, brightness, and speed. These studies have led to the suggestion of a generalized magnitude system in the parietal lobe that processes abstract quantities, with congruency effects across magnitude dimensions. We here turn to an as-yet unexplored dimension in time perception, that of perceived distance. Across three experiments, 60 human participants judged the duration of two visual stimuli, of different sizes, appearing at different spatial locations for a range of sub-second durations. In half of the trials, these stimuli were overlaid on a common scene depicting a city street; crucially, the background context created a relational distance between the two stimuli where one stimulus appeared farther than the other. Our results demonstrated that larger stimuli were judged to be longer in duration when the larger stimulus was perceived as closer (Experiment 1) or farther (Experiment 2); moreover, when both stimuli were the same size, the farther stimulus was judged to be longer in duration (Experiment 3). Curiously, these effects only occurred when the city context was provided; no effect of size on time occurred when a blank background was used, contrary to previous work. These results suggest that larger stimuli are only judged as longer when an appropriate context is provided, and not when the stimuli occur at sufficiently different locations, implying that magnitude judgments are normally computed separately, but interact in particular circumstances. Furthermore, they suggest that when that context includes distance, congruent information influences temporal perception, such that farther, and so relatively larger, stimuli are perceived as longer in duration. These findings suggest a fundamental connection between space and time, and suggest that relational differences are computed on a common scale.

56.312 **Accounting for subjective time expansion based on a decision, rather than perceptual, mechanism** Rakesh Sengupta[1](qg.rakesh@gmail.com), S. Bapiraju[1], Prajit Basu[1], David Melcher[2]; [1]Center for Neural and Cognitive Sciences (CNCS), University of Hyderabad, India, [2]Center for Mind/Brain Sciences (CiMEC), University of Trento, Italy

Events have a subjective duration. It remains an open question whether duration is perceived directly, like a visual feature, or depends mainly on a comparison process. Numerous studies have shown that subjective time experience depends on low-level visual properties and also the attentional focus. In the oddball paradigm, Tse et al (2004) reported that duration judgments for stimuli longer than 120 ms showed temporal expansion. We used a computational model to determine whether a decision-based account of temporal judgments could account for temporal expansion. We used a single layer recurrent dynamic on-center off-surround network of fully connected nodes with self-excitation and lateral inhibition (based on Usher and Cohen, 1999) optimized for winner-take-all dynamics for duration judgements. The 'winner' node, out of the two that receive the inputs of different duration values, determines the duration judgement. One node received the habituated input (standard) and the other received novel input (oddball). We ran a simulation over a range of durations (from 30 ms to 1200 ms) in order to calculate the subjective expansion factor for these durations if they were used as standard duration for oddball trials. The simulation results closely match the pattern of experimental results collected by Tse et al (2004), including the 120 ms cutoff for TSE. These findings suggest that the TSE effect might arise out of comparison process rather than perceived difference in time itself.

56.313 **Visually perceived time dilates with flickering in alpha frequency, but not with flickering in other frequency ranges.** Yuki Hashimoto[1](hashimoto@fechner.c.u-tokyo.ac.jp), Yuko Yotsumoto[1]; [1]Department of Life Sciences, The University of Tokyo

When a visually presented stimulus flickers, its perceived duration exceeds its actual duration. This effect, the so-called time dilation, has been attributed to the number of changes in the event, so that an event with more changes is perceived to be longer. However, recent neurophysiological studies also suggest that time perception is linked to oscillatory neural activity. Here, we hypothesized that the time dilation accompanying a flickering stimulus is caused by interactions between spontaneous oscillatory neural activity and neural synchronization induced by external visual stimuli. A total of 28 subjects participated in three experiments. In all experiments, flickering stimuli with various temporal frequency spectra were presented in pairs, and a point of subjective equivalence (PSE) of 3 s was obtained by two-alternative forced choice. In Experiment 1, a PSE of 3 s with two frequencies, 10.9 Hz (alpha-frequency) and 30 Hz (gamma-frequency) was measured. In Experiment 2, the PSE was obtained with random broadband flicker (RBBF), the temporal profile of which was distributed within a specific range (8-12 or 4-30 Hz), whereas the average temporal frequency was maintained at alpha frequency range. In Experiment 3, RBBF in another range (12-16 Hz), which was not the harmonic of an alpha frequency, was compared with RBBF in an alpha frequency range. When the PSE was smaller than 3 s, time was perceived to be dilated. Time dilation was found with 10.9 and 30 Hz flickers and with 8-12 Hz RBBF, but not with 4-30 Hz RBBF or with 12-16 Hz. These results indicate that a temporal frequency of 8-12 Hz (i.e. alpha) plays a key role in time perception, and that stimulus flickering in alpha frequency, or its harmonics, causes time dilation. The contribution of the alpha frequency implies that time perception is controlled by particular temporal dynamics of synchronized neural oscillations.

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56.314 **Temporal expansion, more information: the role of subjectively distorted time in information accrual** David Melcher[1](david.melcher@unitn.it), Anuj Shukla[2], Andreas Wutz[1]; [1]Center for Mind/Brain Sciences (CIMeC), University of Trento, [2]Center for Neural and Cognitive Sciences, University of Hyderabad

Brief, unexpected events are often experienced as passing in slow motion, as if time subjectively expands. Such time dilation can be measured in an oddball paradigm, in which an infrequent stimulus is perceived to last longer than the standard stimuli in the rest of the sequence. In contrast, time compression occurs when the duration of the standard items in the sequence is brief (Tse et al., 2004). Here, we investigated whether the rate of information processing changes when time is perceived as distorted. We presented standard stimuli of a fixed duration (either 70 or 1050 ms, in separate blocks), each made up of a variable number of green dots, along with a red oddball stimulus of varying numerosity (1-14 items) and duration (30 to 150 ms or 650 to 1250 ms, respectively). Observers had to count the number of dots within the oddball and to judge its relative duration with respect to the standards on that trial. Consistent with previous results, oddballs were reliably perceived as temporally distorted, either expanded for longer (average point of subjective equality: PSE ~ 840 ms) or compressed for shorter oddballs (PSE ~ 100 ms). On a single trial level, enumeration was more accurate when temporal expansion occurred (oddball erroneously judged longer than the standards) and worse when time was subjectively shorter (illusory compression of the oddball). The effect of temporal distortion was maximal for intermediate set sizes for which duration influences information accrual, beyond the subitizing range but still within the range of accurate counting. These findings provide strong evidence for an integration model of time perception, in which the rate of information accrual over an interval determines the perceived duration of the event.

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56.315 **Does cue processing accelerate the onset of inhibition of return?**

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Localization tasks that utilize a cue-target paradigm often produce faster RT at the SOA of 100 ms during valid trials in which target appears at the location indicated by the cue compared to invalid trials in which the target appears at a different location than indicated by the cue. This effect is known as facilitation. However, at the SOA of 300 ms, inhibition of return (IOR) is observed where invalid trials produce faster RT than valid trials. Discrimination tasks also produce the facilitation effect at the SOA of 100 ms, but produce a delayed onset of IOR appearing at the SOA of 700 ms. Our goal is to see whether processing of the cue accelerates the onset of IOR in discrimination tasks. Two white hollow rectangles (1.62° x 1.33°) were presented to the right and left of the fixation cross (retinal eccentricity of 7.31°). One of the two rectangles changed color (to red or green) which served as the cue. Following SOAs of 100, 300, or 1000 ms, the target (a blue or yellow circle) appeared inside one of the two rectangles. Participants performed the discrimination tasks of the target color with three conditions: one condition did not require any processing of the cue, a second condition required the participants to identify the color of the cue, and the last condition required the participants to identify the location of the cue. The results showed facilitation at the SOA of 100 ms and IOR at the SOA of 1000 ms when the participants did not need to process the cue, confirming former findings. Facilitation was also seen at the SOA of 300 ms when the participants identified the location of the cue. However, processing of the cue color or location did not lead to an advanced onset of IOR.

56.316 **A temporal advantage for numerically small digits**

Yong-chun Cai[1](yccai@zju.edu.cn), Shuang-xia Li[1], Shena Lu[1]; [1]Department of Psychology and Behavioral Sciences, Zhejiang University, China

The perceived sequence of events does not always match to their real temporal order. Previous studies have demonstrated that a numerically smaller digit was perceived as appearing earlier than was a large digit when they were simultaneously presented. However, it is disputed whether the temporal advantage of small numbers is due to a faster perceptual processing of small digits or simply reflects a response bias for small numbers. We conducted two experiments to address this issue. A pair of digits (one small and the other large in magnitude) was briefly presented (50 ms) side-by-side on the screen with a stimulus-onset asynchrony varied from -50 to 50 ms. In Experiment 1, we used a temporal order judgment task in which participants judged the side from which a digit appeared first. Numerical magnitude was irrelevant to the task. The point of subjective simultaneity (PSS) was estimated by adopting a curve-fitting procedure. Consistent with previous reports, the PSS was significantly shifted toward the condition that large digits were presented first, so simultaneity could be perceived only if the large digit came slightly before (7 ms) the small digit. This result supports the argument that there is temporal advantage for small numbers during perceptual processing. However, this advantage might simply be due to a response bias for small numbers. To exclude the potential influence of response bias, in Experiment 2, we adopted a simultaneity judgment task in which the participants judged whether the two digits were presented simultaneously or successively. The result indicated that the maximal possibility of simultaneous response was obtained when large digit preceded small digit by 5 ms, suggesting again that small numbers are processed faster than large numbers. Our finding indicates that small numbers are perceived earlier than larger numbers, and that perceptual mechanisms contribute to this temporal advantage.

56.317 **Where's the time? Temporal recalibration is absent without awareness.**

Regan Gallagher[1](regan.gallagher@uqconnect.edu.au), Kielan Yarrow[2], Derek Arnold[1]; [1]School of Psychology, University of Queensland, [2]Department of Psychology, City University

The relative timing at which two sensory events seem synchronous is flexible. Prolonged exposure to temporally offset audio and visual signals (adaptation) results in a distortion of perceived timing; events presented in the same order and near the same offset as the adapted stimuli are more likely to be judged as synchronous. This is known as temporal recalibration (TR). The mechanisms underlying audio-visual timing judgments are not well established, and there is debate concerning the role of attention, with some suggesting that the determination of audio-visual timing takes place pre-attentively, and other evidence suggesting that the relative timing of the two signal streams must be attended. We therefore decided to investigate the role of awareness -- the assumption being that TR should be degraded for subliminal adaptation if conscious attention of timing is required for audio-visual temporal judgments. As a control condition, we measured the tilt aftereffect (TAE), which is known to be robust for subliminal adaptation. We used dichoptic presentations to mask awareness of the dynamics and orientation of visual adaptors and tests. Consistent with previous findings, we found that the TAE could be elicited by either supra- or sub-liminal adaptation. In contrast, we found that only supra-liminal adaptation resulted in a robust TR. These results suggest conscious awareness of the adapting visual dynamics is important for recalibrating temporal relationships, an effect we attribute to the need to consciously attend the adapted audio-visual temporal offset.

56.318 **The temporal decay of unconscious representations in Motion Induced Blindness**

Hsin-Mei Sun[1](sun.hsinmei@gmail.com), Marina Inyutina[2,3], Rufin VanRullen[2,3], Chien-Te Wu[1]; [1]School of Occupational Therapy, College of Medicine, National Taiwan University, [2]Université de Toulouse, CerCo, Université Paul Sabatier, Toulouse, France, [3]CNRS, UMR 5549, Faculté de Médecine de Purpan, Toulouse, France

In motion-induced blindness (MIB), a static target superimposed on a global moving pattern frequently disappears and reappears into consciousness. We previously reported an intriguing illusory temporal reversal whereby a sudden onset stimulus (e.g., a flash) presented during MIB triggers an early reappearance of the target, yet is systematically perceived as occurring after the target reappearance. This illusion implies that the unconscious target representation can be quickly reactivated, with faster conscious access compared to novel stimuli. What is the nature of this unconscious representation: is it a memory of the stimulus that just disappeared, or is it a faithful representation of the input –only unconscious? In the former case but not the latter, the unconscious representation might be expected to decay over time, together with its temporal advantage for conscious access. Here we addressed this question by examining the relationship across observers between the duration of MIB and the percentage of illusory temporal reversals. In the pretest session of regular MIB (200 trials), participants (n = 28) reported the perceptual disappearance and reappearance of a ring target, from which we computed the first (Q25), second (Q50), and third quartiles (Q75) of each participant's MIB duration distribution. In each trial of the test session, after the reported onset of MIB, a dot probe was flashed at the location of the ring at the exact time delay corresponding to either the Q25, Q50, or Q75 value; participants judged the perceived temporal order of the dot and ring. For all 3 conditions, the percentage of illusory reversals was negatively correlated across participants with the corresponding quartile value (p=.01, p=.0001, and p=.02, for Q25, Q50 and Q75, respectively). Therefore, our data suggest that unconscious representations are like a memory that decays over time during MIB and thus decreases its temporal advantage for regaining conscious access.

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Perceptual learning: Specificity and transfer

Tuesday, May 20, 2:45 - 6:45 pm
Poster Session, Jacaranda Hall

56.319 Perceptual learning of detection of band-limited noise patterns

Zahra Hussain[1](zahra.hussain@nottingham.ac.uk), Patrick Bennett[2,3]; [1]University of Nottingham, [2]McMaster University, [3]Centre for Vision Research, York

Perceptual learning has most frequently been studied for discrimination and identification tasks, in which learning is specific to stimuli exposed throughout practice. Here, we asked whether practice improves detection of textures in noise, and whether the improvements, if any, are stimulus specific when stimulus features are not easily identified. We used two external noise levels, following previous studies showing different patterns of improvement in discrimination in low and high noise. Two groups of observers practiced detection of five noise textures (2-4 cpi) on two consecutive days. The texture was presented at one of eight contrasts, including a zero-contrast (signal absent) condition. The observer's task was to detect whether the texture was present or absent on each trial (yes/no). One group practiced the task with the same five textures on both days, and the other group switched to five novel textures on Day 2. Noise levels were blocked, and the five textures were randomly presented throughout the session. We calculated d' at each contrast, and the false alarm rate for each observer in each noise level on both days. Performance improved for both groups in high noise, but the improvement was larger for the same texture group, particularly at high contrasts. Performance improved slightly in low noise for the novel texture group, but not for the same texture group. The improvement in low noise was significantly associated with a reduction in false alarms. The results suggest that learning of texture detection generalizes to novel textures from the same bandwidth, but there is an advantage in high noise for previously exposed textures (i.e., stimulus specificity) despite absence of identification. The low noise data are consistent with work suggesting that threshold improvements in certain yes-no tasks are accompanied by changes in the decision criterion.

56.320 Is improved contrast sensitivity a natural consequence of visual training?

Aaron Levi[1,2](Aaron_Levi@urmc.rochester.edu), Danielle Shaked[2], Duje Tadin[1,2,3], Krystel Huxlin[1,2,3]; [1]Flaum Eye Institute, University of Rochester Medical Center, [2]Dept of Brain and Cognitive Science, University of Rochester, [3]Center for Visual Science, University of Rochester

Performance on many low-level visual tasks improves with practice, with improvements usually limited to trained stimulus and task dimensions. However, in visually impaired populations, e.g., those with cortical blindness or amblyopia, visual training can improve performance on untrained stimuli and tasks (Huxlin et al, 2009; Huang et al, 2008; Zhou et al. 2006). Contrast sensitivity (CS) features prominently among these collaterally improved functions (Huxlin et al., 2009; Polat, 2009). Potential explanations for this include: (1) damaged visual systems possess greater-than-normal plasticity; (2) stimuli/tasks used for rehabilitation induce broad transfer of learning, and (3) CS improvements are a natural consequence of visual training. To test these proposed explanations, three groups of visually intact participants underwent baseline measurement of contrast sensitivity functions (CSFs) for motion direction and orientation discrimination in the periphery. Group 1 then trained on an orientation discrimination task (using 2 cycles/deg, static, non-flickering Gabors). Group 2 trained on a global direction discrimination task previously used to recover motion perception in cortically blind patients (Huxlin et al., 2009). Group 3 underwent no training. After 10 days, the battery of CS measurements was repeated. While both forms of training improved CS, Group 1 exhibited its largest enhancement for CSFs measured with static stimuli similar to those used during training, whereas Group 2's CS improvements occurred in functions measured with moving or flickering stimuli. Group 2 also exhibited enhancements over a broader ranger of spatial and temporal frequencies. Group 3 generally saw no significant CSF improvement from test to re-test. Thus, CS improvements appear to be a consequence of many, disparate forms of visual training, while retaining some degree of specificity for basic attributes of the trained stimulus. It remains to be determined whether CS improvements are critical for visual learning, or whether they are a simple by-product of repetitive visual training.

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56.321 Eye and location specificity of perceptual learning of contrast detection

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In this study, we carried out a psychophysical experiment to measure the eye and location specificity of contrast detection learning. Five subjects underwent thirty daily training sessions to detect a near-threshold circular checkerboard (eccentricity: 4°; location: lower-left or lower-right visual quadrant; diameter:5°; spatial frequency:1 cycles/°; mean luminance:16 cd/m2). Subjects was trained with only one eye. A daily session consisted of 30 QUEST staircases of 40 trials. In a trial, the checkerboard was presented in one of two 200 ms intervals. Subjects were asked to make a 2-AFC judgment of the interval in which the checkerboard appeared. Before and after training, we measured subjects' contrast detection thresholds in four conditions (with reference to the trained stimulus): the same spatial location in the same eye, the same location in the opposite eye, the opposite spatial location (i.e. the opposite visual field) in the same eye, and the opposite location in the opposite eye. After training, subjects' performance improvements in the four conditions were 6.76%, 2.33%, 12.42%, and 24.57%, respectively.On one hand, the moderate transfer between spatial locations in different visual fields suggests that some high-level mechanisms play a role in the contrast detection learning. On the other hand, the little transfer between two eyes implies a significant monocular component in the learning. Future brain imaging and neurophysiological studies should investigate if contrast detection learning could modify the functional properties of monocular neurons in V1 and LGN.

56.322 The Effect of Priming on Contour Integration Training

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Top-down influence over short timescales (e.g. shape priming) has been shown to greatly improve success on high difficulty visual integration tasks by increasing salience, and over longer timescales, visual integration task training has resulted in enhanced visual integration performance. However, the possible benefit for task performance from combining the more immediate influence of shape priming with task training has not been explored. The aim of the present study was to determine if training in contour integration with added shape priming cues would improve performance on a contour integration task that has well-established psychometric properties. Subjects first briefly viewed a series of Gabor element displays with embedded contours forming shapes with the task of indicating which direction the shape was pointing (up, down, left, or right). A baseline threshold for target shape recognition was established. Task difficulty was determined by amount of jitter in orientation of the embedded contour elements. Perceptual threshold was established utilizing a staircase procedure. Subjects were then randomly assigned to training either with contour priming or without contour priming for 30 minutes a day, starting after baseline assessment, for a total of three consecutive days. After training on day 3, perceptual threshold was measured utilizing the same procedure as used at baseline. Using a two-way repeated measures analysis of variance it was established that both groups showed a significant decrease in perceptual threshold from baseline to post training assessment, but the effect of priming was not significant. These findings suggest that the top-down influence of shape priming does not modulate perceptual learning associated with visual contour integration training.

56.323 Motion discrimination learning improves perceptual representation and accelerates sensory evidence accumulation

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Purpose: By combining behavioral paradigm of perceptual learning (PL) and diffusion model (DM) of perceptual decision (PD), previous studies have found that PL can increase drift rate, a parameter that represents the rate of sensory evidence accumulation in PD process. Here we conducted an fMRI experiment to investigate the neural mechanism of such learning-related facilitation effect. Methods: We trained participants on a motion discrimination task for ten days. Before and after the training, participants' motion discrimination sensitivity was measured inside the scanner. Behavioral data were analyzed with linear ballistic accumulator model (LBA). LBA has the advantage over the traditional DM for its convenience in estimating the single trial parameters. Preprocessed fMRI data were decomposed with spatial group independent component analysis (ICA). Robust ICs were deconvolved to extract the single trial brain

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activity. The trial-to-trial co-fluctuation between the parameters of the LBA model and the fMRI activity was considered as the indicator for the involvement of a brain area in the representation of the model parameters. Results: (1) Behavioral results: Training significantly improved the motion direction discrimination sensitivity around the trained direction specifically. (2) Modelling results: The behavioral training effect could be attributed to the increased drift rate that was specific for the trained direction. (3) fMRI results: V3A and MT+ showed a specific decrease in fMRI signal to the trained direction. However, the learning-related trial-to-trial fluctuation of the drift rate correlated only with the activity of V3A. Conclusion: These results suggest that PL improves the perceptual representation of the motion stimulus along the trained direction. This improvement subsequently speeds up the process of sensory evidence accumulation in PD and may account for the observed behavioral learning effect. The neural signature of the transition from the improved perceptual representation to the accelerated PD process was observed in area V3A.

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56.324 **The influence of perceptual learning on visual context illusions** Karin Ludwig[1,2](karin.ludwig@charite.de), Maria Lev[3], Sharon Gilaie-Dotan[4], Stephanie Voss[1], Philipp Sterzer[1], Uri Polat[3], Guido Hesselmann[1]; [1]Visual Perception Laboratory, Charité – Universitätsmedizin Berlin, Germany, [2]Department of Psychology, Humboldt-Universität zu Berlin, Germany, [3]Faculty of Medicine, Goldschleger Eye Research Institute, Tel Aviv University, Israel, [4]UCL ICN London, United Kingdom

A recent study found that the surface area of primary visual cortex (V1) of healthy adults correlates with the magnitude of the Ebbinghaus illusion, such that individuals with larger V1 have a smaller illusion effect. Since the illusory effect in visual context illusions is based on contextual modulation by adjacent or surrounding stimuli, these results were presumed to be due to differences in neuronal lateral connections between small and large visual cortices (Schwarzkopf, Song, & Rees, 2011). Here we sought to investigate whether visual illusion magnitude correlates with spatial vision (lateral masking and crowding) and whether a perceptual training that is known to modulate lateral masking and crowding will lead to a change in perception of the illusions. We measured the illusion magnitudes of three visual context illusions, the Ebbinghaus, the tilt, and the orientation-dependent contrast illusion, before and after two months of perceptual training in a group of 14 young healthy adults. The perceptual training consisted of detecting Gabor stimuli in the presence of lateral masks and has been shown to reduce spatial and temporal masking (Polat et al., ECVP 2013). It was carried out on iDevices at a distance of 40 cm (GlassesOff application). Before the training, illusion magnitudes of the Ebbinghaus and the tilt illusion significantly correlated with the strength of lateral masking and crowding, which are assumed to rely on lateral interactions. After training we found a reduction in all three illusion measurements indicating a diminished influence of the surround on the perception of the center. We conclude that a reduction of lateral inhibition through perceptual learning leads to a more veridical – i.e., less illusory – impression of the visual world.

56.325 **Learning and transfer of feature-based attentional modulation** Anna Byers[1](abyers@ucsd.edu), John Serences[1,2]; [1]Department of Psychology, UCSD, [2]Neurosciences Graduate Program, UCSD

Recent evidence suggests that some cases of learning are supported by improvements in top-down attentional control that transfers across spatial location (e.g. Xiao et al., 2008; Zhang et al., 2013). Since feature-based attention is considered to be spatially global, training feature-based attention could lead to generalized and transferrable improvements in attentional modulations (Byers & Serences, 2012). We conducted two experiments to test whether feature-based attention modulates learning and transfer and the role of hemispheric spatial attentional resources in learning (see Alvarez et al., 2012). In Experiment 1, subjects trained on a 2AFC motion coherence discrimination task, which employed valid and invalid feature cues and 6 motion coherence levels. Subjects trained for four days with the stimuli located either to the left, right, above, or below fixation; on the 5th day, the stimuli switched to the opposite position (e.g. left to right, top to bottom; see Supplemental Figure). Learning, quantified as a leftward shift in the psychometric function, occurred across positions but was only modulated by the attentional cue in subjects who trained in the top/bottom position. To the extent that subjects learned, these improvements also transferred to the untrained spatial position. A follow-up experiment examined interactions between learning and both space- and feature-based attention. Subjects trained on a 2IFC motion coherence detection task and were given a feature cue, a space cue, both cues, or an uninformative neutral cue on each trial. Preliminary data suggest that initial performance was best with the combined cue and the spatial cue and initial performance on feature-cued trials was equivalent to neutral trials. However, performance on the feature-cued trials relative to neutral trials improved with learning and this attention effect transferred across spatial position. Together, these data suggest that training can enhance feature-based attentional modulations and that these enhancements transfer across spatial locations.

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56.326 **Exogenous attention facilitates perceptual learning transfer within and across visual hemifields** Ian Donovan[1](ian.donovan@nyu.edu), Sarit Szpiro[1], Marisa Carrasco[1,2]; [1]Department of Psychology, New York University, New York, NY, USA, [2]Center for Neural Science, New York University, New York, NY, USA

Goal. Visual perceptual learning (VPL) is usually specific to the trained retinal location, which is often attributed to plasticity in early visual cortex. Recent findings show that VPL transfers to untrained locations given specific training procedures. For instance, exogenous attention has been found to transfer VPL to untrained, distant locations. Here, we investigated whether exogenous attention differentially affects transfer within and across visual hemifields, thereby comparing different cortical distances while holding retinal distance constant. Methods. Observers completed an orientation discrimination task on 5-consecutive days. They reported the orientation of a single Gabor patch of varying contrast. On the Pre– and Post–tests (sessions 1 and 5, respectively), the target was presented at one of 4 peripheral locations, equidistant from fixation and the vertical and horizontal meridians. During Training (sessions 2-4), the target appeared at one of 2 locations: both on the same side of either the vertical meridian (Same–Hemifield) or horizontal meridian (Different–Hemifield). During Training, half of the observers in each group were presented with a peripheral pre-cue adjacent to the target location (Cued-group) and the other half with a neutral cue at fixation (Neutral-group). Results. We assessed VPL at trained and untrained locations as the change in performance (d') between Pre– and Post–tests. Whereas for the Neutral condition learning occurred at the trained but not untrained locations, for the Cued condition there was significant learning in both trained and untrained locations. This pattern of results emerged to a similar extent for both Hemifield conditions. These results reveal that attention facilitates transfer of VPL to untrained locations both within and across visual hemifields. This finding suggests that attention's benefits are interhemispheric and likely mediated by both low and higher visual cortical areas.

56.327 **Exogenous attention enables visual perceptual learning and task transfer** S.F.A. Szpiro[1](sarit.sz@gmail.com), S. Cohen[1], M. Carrasco[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Goal. Perceptual learning is a long lasting improvement in performance following training. Attention has been shown to enhance performance and facilitate transfer across locations. Here we examine whether attention also: (1) enables learning when it would otherwise be absent; (2) facilitates transfer across tasks; (3) facilitates transfer across features. Methods. We used 2AFC orientation and spatial frequency comparison tasks, for which the standard stimulus was the same. On each trial, two Gabor patches appeared–a standard and a comparison. Observers compared either their orientation (and reported which one was more clockwise) or their spatial-frequency (and reported which one was of higher frequency). During Pre- and Post-tests (Days 1 and 5, respectively), observers were tested on both tasks with a standard Gabor (4-cpd oriented 30° or 120°) using a neutral cue. During Orientation Training (Days 2-4, 800 trials per day), observers compared the orientation of two 4-cpd stimuli, one which was always oriented 30° (standard stimulus). Half the participants trained with a central-neutral cue (Neutral-group) and the other half trained with peripheral cues adjacent to the two upcoming stimuli (Attention-group). Results. For the Neutral group there was no learning effect in either task. In contrast, the Attention group showed learning overall: For the trained orientation task, there was learning for the trained stimulus (30°), but not for the orthogonal untrained stimulus (120°). For the untrained spatial-frequency task, learning emerged for both the trained and untrained stimulus orientations. Conclusions. This study shows that training with a neutral cue does not yield learning, whereas training with exogenous attention: (1) enables perceptual learning when otherwise absent; (2) facilitates transfer across tasks; and (3) facilitates transfer across features for the untrained, but not the trained, task. These findings further our understanding of the benefits of attention–it enables perceptual learning when otherwise absent.

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56.328 Spatial attention generalizes perceptual learning to untrained locations in an acuity task

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Background. Visual perceptual learning (VPL) refers to improved performance following visual training, and is usually specific to trained retinal locations. However, covert spatial attention has been shown to generalize VPL to distant untrained locations in contrast sensitivity tasks. We investigated whether this finding generalizes to another basic dimension: visual acuity. We tested the effects of exogenous (involuntary) attention on VPL at both trained and untrained locations using an acuity task. Procedure. Two Landolt-squares were presented diagonally at isoeccentric locations. Each Landolt-square had a gap of varying size on the left or right side. A response cue indicated which stimulus was the target. Participants reported whether the target square had a gap on the left or right side. On the Pre- and Post-tests (1st and 5th sessions, respectively), performance was measured for the two diagonal pairs. During the intermediate Training sessions (2nd, 3rd and 4th sessions), only locations at one diagonal were tested (trained locations). Observers were divided into two training groups: a Neutral group, for which a central pre-cue was presented at fixation, and an Attention group, for which a peripheral pre-cue appeared adjacent to the upcoming target location. Both testing sessions employed neutral cues and were identical for the two groups. We derived psychometric functions and calculated 75% contrast thresholds. VPL at trained and untrained locations was assessed by changes between Pre- and Post-tests in overall performance and gap-size 75%-threshold. Results. We found a standard VPL pattern for the Neutral group: performance improved and threshold decreased more at trained than untrained locations–location specificity. However, for the Attention group, performance improved and threshold decreased at both trained and untrained location–no location specificity. Conclusion. Exogenous attention generalizes VPL to untrained locations in an acuity task, providing converging evidence that attention helps generalize learning.

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56.329 Perceptual learning for multiple features: Neural correlates of changes in sensitivity and bias

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Accumulating evidence suggests that multiple levels of processing and representation may be involved in perceptual learning, and that tasks assumed to reflect low-level changes in perceptual sensitivity may be subject to a variety of high-level influences. For example, organizing patterns of contrast as meaningful stimuli (e.g., faces vs. textures) supports higher levels of performance than with equivalent levels of contrast in non-meaningful stimuli. With respect to representation, the possibility of multiple sources of influence raises at least two questions: can perceptual learning be accomplished with multiple features, and if so, what are the informational relationships among the learned features? That is, to what extent are these acquired representations dependent or separable, either perceptually or decisionally? The present study investigates these questions using stimuli (sized to be completely foveated) containing 0, 1 or 2 contrast-defined target pattern features, drawn from the 1865 drawing of the Cheshire Cat in Alice's Adventures in Wonderland. Participants began by performing a complete identification task (CID), in which stimuli contained 0, 1, or 2 of the components of the target image, presented at either 50% or 10% contrast. They then practiced with all possible stimuli for 10-15 days, using an adaptive staircase procedure to track thresholds. Finally, they again performed the CID, with stimuli presented at 50%, 10% and threshold contrast levels. EEG data were collected during both pre- and post-practice performance of the CID. Reliable reductions in thresholds were accompanied by reliable shifts in decisional criteria, the emergence of violations of separability, and increases in the amplitude of early ERP components and power in gamma-band activity. These results suggest that perceptual learning can be obtained with multiple features and that learning can involve interacting sources of information at both perceptual and decisional levels.

56.330 Sensory and expectation cues are fused during perception

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Observers perceive expected visual stimuli faster and more accurately. Here we explore how, at the computational level, expectations facilitate perceptual processing. Sensory cues and expectations may independently contribute information about perceptual features to decision-making processes. Alternatively, information provided by sensory cues and expectations could be integrated into a "fused" feature representation (in a process analogous to maximum likelihood estimation) prior to perceptual decision-making. Using psychophysical techniques originally developed to study cue combination in depth perception, we sought to test whether humans fuse sensory and expectation cues. First, we developed a perceptual matching task that led participants to map a continuous range of tone frequencies onto a corresponding distribution of face stimuli ranging in gender from male to female. Next, to test for fusion, we measured the sensitivity of participants in a gender discrimination task as we varied the strength of sensory cues (i.e., faces of varying gender) and expectation cues (i.e., tones of varying frequencies). On each trial, two faces were presented sequentially, each preceded by a predictive tone. Differences in gender could be conveyed by differences in the visual stimuli (stimulus-alone condition), the predictive tones (expectation-alone condition), or both (congruent condition). If expectation and sensory cues are represented independently, sensitivity in the congruent condition should correspond to the quadratic sum of the sensitivity in the stimulus- and expectation-alone conditions. In contrast, if stimulus and expectation cues are fused, sensitivity should disproportionately suffer in the stimulus- and expectation-alone conditions because perceptual representations will be compromised by noise from the uninformative cue; as a result, sensitivity in the congruent condition will exceed quadratic summation. Consistent with this latter possibility, discrimination sensitivity exceeded quadratic summation in the congruent condition. These results provide the first evidence that stimulus and expectation cues are fused, analogous to the cue fusion found in low-level vision.

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56.331 Learning of hierarchical temporal structures facilitates the prediction of future events

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Previous experience is thought to facilitate our ability to extract spatiotemporal regularities from cluttered scenes. Recent work has focused on simple structures defined by associative pairing, or probabilistic sequences. However, event structures in the environment are typically hierarchical, comprising of simple repetitive to more complex probabilistic combinations (e.g. as in language, music, navigation). Here we test whether exposure to temporal sequences facilitates our ability to learn hierarchical structures and predict upcoming events. In particular, we employed variable memory length Markov models to design hierarchically structured temporal sequences of increasing complexity. We presented observers with a sequence of four different symbols that differed either in their probability of occurrence (0.2, 0.8, 0, 0) or the length of the predictive temporal context (up to a context length of two sequence items). Observers were first trained with sequences determined only by probability of occurrence and then variable context length (first context length of one item, then context length of two items). In each trial, the sequence was interrupted by a test stimulus and observers were asked to indicate whether the test symbol matched their expectation based on the preceding sequence. Our results demonstrate different learning profiles for hierarchically structured sequences across observers based on probability maximization vs. matching. Successful learners learned quickly (within 2 training sessions) to predict the most frequent symbol for each context (i.e. probability maximization). In contrast, weak learners based their predictions on symbol probabilities (i.e. probability matching) and required more (4-5) training sessions to learn the correct hierarchical structure. This predictive learning ability was compromised when symbol probabilities were less discriminable, but not when the sequence structure was less constrained. These findings suggest that learning context-dependent probabilities rather than memorizing temporal positions in hierarchical structures facilitates the prediction of upcoming events in complex environments.

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56.332 Perceived Stability of Composite Material Objects

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An object's centre of mass (COM) is determined by its shape and density distribution. To assess whether the human visual system can detect an object's COM from both shape and material properties, we created computer-generated images of goblets made of different materials (e.g., glass, polystyrene) that were either uniform or made of composite materials (e.g., glass and gold) and positioned upright or upside down near a table ledge. Observers were instructed to indicate whether the goblet was more likely to fall off the table or right itself. The critical angle (CA), the angle at which the goblet is equally likely to fall or right itself, was used as a measure of perceived object stability. Participants rank-ordered materials by density on a questionnaire after completing the experiment. If object stability were judged in accordance with physical laws, then we would expect no change in the CA across uniform material objects, while we would expect differences in the CA depending on the relative position of materials for composite material objects. The results show that observers correctly recognize that change to a uniform object's material will not affect its stability. Importantly, perceived and true material density were positively correlated suggesting that observers have a good representation of relative material density. Results for composite material objects revealed that the perceived CA changes with the true CA, suggesting that observers use this accurate representation of relative material density to assess object stability. We conclude that the human visual system is able to form a reliable estimate of an object's COM from shape geometry and material properties that is used to assess an object's behaviour.

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56.333 Age-Related Differential Transfer of Improved Contrast Sensitivity with Perceptual Learning

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Research has demonstrated widespread age-related declines in visual function. Previous research has shown that perceptual learning (PL) techniques can be used to help counteract these age-related declines, and have been successfully used to improve motion discrimination (Bower & Andersen, 2012), as well as fine orientation discrimination in older individuals (DeLoss, Watanabe & Andersen, In Press, Vision Research). The present study examined whether contrast sensitivity could be improved in older adults using a coarse orientation discrimination task. Eight older individuals (mean age 72.13, range 67-84) and eight younger individuals (mean age, 21.29, range 19-23) participated in the experiment, which consisted of seven 1.5-hour sessions. A two-interval forced choice procedure was used during which two sequentially presented Gabor patches were presented. Participants indicated whether the Gabor in the second interval was rotated clockwise or counter-clockwise relative to the first, this rotation was set to a constant of 15 degrees. On days 1 and 7 pre-training and post-training contrast thresholds were determined using QUEST for a trained and an untrained standard (+/- 25 degrees off vertical), both measured at five different levels of external noise. Testing order and trained standard were both counter-balanced across subjects. During days 2 through 6 participants completed 750 trials at their assigned orientation standard, with 150 trials at each of the five levels of external noise presented on the testing days. Results showed improved contrast sensitivity for younger and older individuals for their trained standard. However, older individuals showed significant and nearly complete transfer to the untrained orientation, while younger individuals showed no significant transfer to their untrained orientation. The significance of these findings for perceptual learning, and specificity, in both younger and older individuals will be discussed.

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56.334 Training as Part of a Word Game Increases Reading Speed in Peripheral Vision

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Purpose: Patients with central-field loss from macular degeneration must rely on their peripheral vision to read, which is slow and difficult even for normally sighted subjects. Our lab has demonstrated that intensive perceptual training on a trigram (three adjacent letters) letter-recognition task in peripheral vision is effective in increasing peripheral reading speed of normally sighted subjects by 40% or more (e.g. He, Legge & Yu, Journal of Vision, 2013). To make this tedious training more enjoyable and motivating, we have incorporated the trigram training into a word game, similar to the popular TV show Wheel of Fortune. In the game, correct trigram responses yield clues to category items such as world cities. Here we evaluated the resulting training benefits in comparison with traditional trigram training. Method: Six young, normally sighted subjects in the gaming group (G) played our game for four days, 1.5 hours/day, matching the training time of a traditional training group (T). Since adding the game reduced the number of training trials in group G to half of that in group T, another four subjects in a long-gaming group (L) were trained for six days, 2 hours/day to match the number of training trials to group T. RSVP reading speed was measured in pre- and post-tests. Results: For all three groups, reading speed improved significantly after training, and the improvement did not differ significantly between groups. Conclusions: Our game-based training produces the same benefits for reading speed as the traditional trigram training with half the number of trigram trials, but longer game-playing did not produce extra benefit. Although the gaming component increases the training time, it also produced elevated interest and motivation during the training, making the game-based training potentially more acceptable for a clinical population.

Acknowledgement: Supported by NIH grant EY002934

56.335 Perceptual learning improves near vision in pilots with eye aging.

Anna Sterkin[1,2](anna.sterkin@gmail.com), Oren Yehezkel[2,3], Maria Lev[1], Ravid Doron[1], Moshe Fried[1], Yuval Levy[4], Liora Levian[4], Reuven Pokroy[4], Barak Gordon[4], Uri Polat[1,2]; [1]Faculty of Medicine, Goldschleger Eye Research Institute, Sheba Medical Center, Tel Aviv University, Israel, [2]GlassesOff Inc., USA, [3]School of Optometry and Helen Wills Neuroscience Institute, UC Berkeley, Berkeley, CA, USA, [4]IDF Air Force, Israel

Background: Presbyopia is a process in which uncorrected near visual acuity results in blurred images, progressing with age starting around the age of 45. Our earlier studies have shown significant improvement in near visual acuity (VA) in presbyopes following training protocol based on perceptual learning, with persistence of up to 6.2 years and effectiveness in improving distance VA in young with consequent improvement in higher visual functions, such as reading. Our hypothesis is that both improvements in contrast sensitivity and processing speed underlie the observed gains in visual functions. Israeli Air Force pilots continue flying combat missions past the age of onset of presbyopia. Any optical correction for presbyopia limits their flying capabilities. Therefore, there is an operational need for delaying the onset of presbyopia or improving their near VA in order to avoid the use of optical corrections. Aim: Here we aimed to 1) test whether the temporal processing of pilots that is commonly assumed superior compared to age-matched controls, leads to advantage in visual functions and 2) improve pilots' near VA using our perceptual learning method. Methods: 30 pilots with both early and advanced presbyopia completed a training protocol for presbyopia (GlassesOff mobile application for iOS devices), consisting of a 12-15 minute session, 3 times a week for 3 months. Results: 1) pilots showed a significant advantage in processing speed measurements compared to controls. 2) Despite this initial advantage, pilots showed significant improvement following the training protocol in several basic visual functions, such as contrast sensitivity, contrast discrimination and temporal processing. These training gains were also reflected in higher visual functions, such as reading and low-contrast aerial photography interpretation. Conclusions: Training protocol for presbyopia is effective for overcoming the blurred vision in presbyopic pilots, despite their initial temporal processing advantage compared to controls, with real operational benefits.

Acknowledgement: Israel Science Foundation, IDF Medical Corps, GlassesOff Inc., NY, USA

56.336 "Edward Rake-Hands" Part II: Does embodiment of a real tool occur via virtual tool interaction?

Kimberley Jovanov[1](kim.jovanov@mail.utoronto.ca), Paul Clifton[2], Ali Mazalek[2], Michael Nitsche[2], Timothy N. Welsh[1]; [1]Centre for Motor Control, Faculty of Kinesiology & Physical Education, University of Toronto, [2]Digital Media, Georgia Institute of Technology, Atlanta, GA, USA

The present study investigated the incorporation of task-specific objects into our body schema (i.e., tool appropriation/embodiment). Previous research on tool appropriation suggests that, through physical interaction with a tool, the representation of our body is adjusted to "embody" the tool. The present experiment considered the different mediums in which a tool-use can be learned. To this end, participants were asked to complete an adapted body-part compatibility task before and after completing a real or virtual tool interaction task in which they moved objects around with a rake (participants used buttons on a keyboard to control the rake in the virtual

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task). Participants were presented with images of a person holding a rake and were required to execute hand- and foot-press responses to coloured targets (red and blue, respectively) superimposed on the hand, foot and rake of the image. Consistent with previous research on the body-part compatibility effect, response times (RTs) were shorter when the responding limb and the target location were compatible (e.g., hand responses to targets on the hand) than when they were incompatible (e.g., hand responses to targets on the foot). Evidence for tool embodiment after real experience was observed because hand RTs to targets presented on the hand were shorter than RTs to targets on the rake prior to experience, but there was no difference between RTs to targets on the hand and rake after the real rake task. The similarity in RTs emerged because there was a significant reduction in RTs to targets on the rake following experience. In contrast, hand RTs to targets on the rake did not change with virtual rake experience. These data suggest that the virtual tool interaction in the present experimental conditions was not sufficient for participants to embody the tool.

Acknowledgement: NSERC

56.337 **Learning to Recognize Faces by How They Talk** Dominique C. Simmons[1](dsimm002@ucr.edu), Josh J. Dorsi[1], James W. Dias[1], Theresa C. Cook[1], Lawrence D. Rosenblum[1]; [1]University of California Riverside

Seeing speech articulations can facilitate face recognition when other visual information is degraded (Lander & Chuang 2005). Furthermore, observers are able to identify familiar faces when visual information is reduced to visible articulation (Rosenblum et al., 2007). The question at hand is whether observers can learn to recognize unfamiliar faces based on visible articulatory information. We investigated this question using point-light displays of 10 articulating faces. We created point-light displays by placing fluorescent dots on each speaker's face, mouth, teeth, tongue, and lips. Nine different point-light configurations for each speaker were used so that subjects would be unable to use point pattern information for recognition. The 10 speakers were then filmed against a black background saying the sentence, "The football game is over." Eighteen undergraduates were first shown a single clip of each talker and told the talker's name. During training, subjects saw 4 clips of each speaker, presented randomly, and attempted to identify the speakers by pressing a button labeled with speaker names. Subjects received immediate feedback following each trial. During the test phase, participants were presented with the remaining 4 video clips and attempted to identify the same 10 speakers without feedback. Results showed that subjects learned to recognize all of the speakers at better than chance levels, $t(17) = 8.70$, $p < .001$. Initial tests using single frames of point-light videos indicate that identification accuracy substantially declines for learning to recognize faces from static point-light images. The results suggest that observes can learn to use talker-specific articulatory movements for face recognition.

56.338 **Individual differences in sleep-dependent perceptual learning: Habitual vs. non-habitual nappers** Elizabeth McDevitt[1](mcdevitt@ucr.edu), Lauren Whitehurst[1], Katherine Duggan[1], Sara Mednick[1]; [1]Department of Psychology, University of California, Riverside

We examined the effect of napping behavior on the enhancement of perceptual learning (PL) during sleep. In a mini-longitudinal study, habitual and non-habitual nappers were randomly assigned to five weeks of nap practice (at least 3 naps per week) or nap restriction (no naps). PL was tested pre- and post-intervention using a texture discrimination task in a nap paradigm (with texture targets tested in different spatial locations at each time point). For each visit, we calculated a within-day difference score between morning and evening test sessions to measure performance change following an EEG-recorded nap. At time point 1, habitual nappers showed PL following a nap, whereas non-habitual nappers did not show improvement. At the end of the intervention, at time point 2, both habitual nappers restricted from napping and non-nappers practicing napping showed lower magnitude of PL than the habitual nappers allowed to nap and non-nappers restricted from napping. That is, when napping behavior was congruent with nap habits, typical sleep-dependent PL occurred. When napping behavior and habits were incongruent, PL was not found. We found no differences in the amount of each sleep stage between habitual and non-habitual nappers. However, during non-rapid-eye-movement sleep, habitual nappers produced greater sleep spindle densities over parietal and occipital sites, as well as greater slow wave activity power density over central and parietal sites. In conclusion, although sleep, including naps, has been repeatedly demonstrated to play an important role in the consolidation of PL, the results from our experimental intervention indicate that napping may only benefit PL in people who habitually nap. These differences may be related to the magnitude of specific sleep features. Furthermore, altering a person's normal sleep/wake rhythm by adding or removing naps may not be beneficial for cognitive performance.

Spatial vision: Models

Tuesday, May 20, 2:45 - 6:45 pm
Poster Session, Banyan Breezeway

56.401 **Does the size really determine the size congruency effect? The role of height in the perception of quantity** Liat Goldfarb[1](goldfarb@edu.haifa.ac.il); [1]E.J.S Brain Research Center, University of Haifa

It has been suggested that the ability to perceive quantity depends on size perception. This can be demonstrated by the robust size congruency effect in which RT for deciding which digit is numerically larger, is faster for congruent size-numerical pairs (e.g., 1 9) than incongruent pairs (e.g., 1 9) (e.g.: Besner & Coltheart, 1979). In previous size congruency experiments, the change in the size dimension was confounded with changes on the height and width dimensions. Hence, this study explores if indeed the size determines the size congruency effect. Do two digits that are equal in size but with different width and height produce a similar congruency effect and if so which dimension (height or width) is actually associated with quantity? Since numbers are arranged horizontally in a line, arranged on the width dimension, then wider digits might be associated with larger numbers. Alternatively, some researchers (e.g.: Piaget & Inhelder, 1974) suggested a developmental primitive mechanism in which higher objects are perceived as containing more substance. The current study included two experiments in which two equal size digits were presented and participants were asked to decide which digit is numerically larger. In Experiment 1, each digit was created from bricks that differed from each other in the height and width dimensions. In Experiment 2, each digit was embedded in a taller or wider glass figure. The result revealed that although the digits were equal in size, a congruency effect was observed so that a congruent pair emerged when the numerically larger digit was also higher (Exp 1) or was embedded in a taller glass (Exp 2). The relationship between quantity and the mechanism that perceives the height (and not the width) dimension is further discussed.

56.402 **Optimizing the estimation of differences between psychometric functions** Nicolaas Prins[1](nprins@olemiss.edu); [1]Department of Psychology, College of Liberal Arts, University of Mississippi

Many adaptive testing methods have been proposed to optimize the efficiency with which the parameters (e.g., threshold, slope) of an individual psychometric function (PF) can be estimated. However, researchers are rarely interested in the value of the parameters of an individual PF per se. More often, researchers are interested in detecting an effect that some experimental manipulation has on these parameters. In other words, researchers are generally interested in the difference between parameter values measured under different experimental conditions. Here, I modify the Bayesian adaptive psi-method (Kontsevich & Tyler, 1999, Vision Research, 39, 2729-2737) in order to optimize the estimation of differences between the parameter values of a pair of PFs. The method maintains and updates, on a trial-by-trial basis, a posterior distribution defined across four parameters: the mean of the two thresholds, the difference between the thresholds, the mean of the two slopes, and the difference between the two slopes. On each trial, the method selects both which of the two PFs should be tested and which stimulus intensity should be used. The criterion by which the method makes these selections is the expected gain in information regarding the values of the difference parameters only. Results of computer simulations indicate that the optimization of estimation of difference parameters leads to a somewhat different placement strategy compared to optimization of parameter values of individual PFs. However, this placement strategy does not result in more efficient detection of differences between parameter values. Results also indicate that estimation of difference parameters is very robust to incorrect assumptions regarding the value of the lapse rate. That is, even though the estimates of the mean parameter values are biased when the generating lapse rate differs from the lapse rate assumed by the method, the estimates of the difference parameter values are relatively unbiased.

56.403 **A model of symbol discrimination in vibration blur** Albert Ahumada[1](al.ahumada@nasa.gov), Bernard Adelstein[1], Andrew Watson[1], Brent Beutter[1], Giovanna Guerara-Flores[2]; [1]NASA Ames Research Center, [2]San Jose State University Foundation

Because crews in aerospace vehicles can be exposed to significant vibration, Adelstein, Kaiser, Beutter, McCann, and Anderson (Acta Astronautica, 2012) examined the effect of vibrating observers at 12 Hz on their ability to read numeric symbols on stationary displays and found performance degradation with increasing vibration amplitude. The observer's task was to read a trigram of digits and respond by pressing the right button if the digit sequence was monotonic increasing or pressing the left button if was not. They also showed the efficacy of a display-strobing countermeasure for the reading decrements. We have adapted the model of Watson and Ahumada (J. Vis., 2008) for predicting letter identification in the presence of optical blur to the prediction of the effects of sinusoidal vibration blur on their reading task. The blur kernel was the one dimensional orthogonal projection of a circle. The model can account for the degradation caused by motion blur and the release from degradation resulting from strobing the backlight of the display with varying strobe duty cycles.

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56.404 Aggregating multiple judgments in a mixed-strengths signal detection task

Mordechai Z. Juni[1](juni@psych.ucsb.edu), Miguel P. Eckstein[1]; [1]University of California, Santa Barbara

Signal detection accuracy is susceptible to internal, sensory-driven noise and to external, stimulus-driven uncertainty. Combining multiple observers' judgments leads to well-known benefits for optimal integration (Sorkin & Dai, 1994), and lower but comparable benefits for majority-rule aggregation (Eckstein, Das, et al., 2012). However, such theoretical analyses and empirical studies use a signal of a single strength while real-life tasks often present a mixture of signal strengths, which makes some instances of the signal much easier to detect than others (e.g., some mammograms contain very large lumps while others contain very small lumps). Here, we simulated and conducted a detection task with a random mixture of high and low signal strengths. Each observer (N=20) participated alone in two conditions on separate days (counterbalanced). On each trial, observers responded on an 8-point confidence scale whether a Gaussian signal (σ=0.15o) was embedded in white noise (signal present 50% of the time). In the single strength condition, the signal always had 11% contrast (SNR=4). In the mixed strengths condition, half of the signals had 7% contrast (SNR=2.54) while the other half had 16% contrast (SNR=5.81). All observers viewed the same exact stimuli but in randomized order, and their individual d-primes were approximately the same for the two conditions (d'≈1.45). As expected, aggregating judgments across observers leads to higher d-primes; but these higher d-primes are 5% to 10% lower in the mixed strengths condition relative to the single strength condition (depending on the number of judgments that are combined). This is because observers' judgments during signal present trials have a heightened correlation in the mixed strengths condition relative to the single strength condition. These results highlight why the aggregations of judgments for real-life stimuli tend to generate less accuracy benefits than theoretically predicted and typically observed for synthetic stimuli where signal strength is usually constant.

56.405 A psychophysically derived model of signal combination predicts neural responses in two stimulus domains

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How closely do computational models derived to understand psychophysical data relate to neural activity? Steady-state EEG provides a measure of the response of neural populations to visual inputs. Here, this technique is used to test the predictions of a general model of signal combination and suppression, recently proposed by Meese & Baker (2013, iPerception, 4: 1-16). Stimuli were 1c/deg gratings presented either to the left and right eyes (to test binocular combination) or interdigitated across space in micropatch 'checks' of four cycles (to test combination across space). The two components (left and right eyes, or adjacent spatial locations) flickered at either the same frequency (5Hz), or different frequencies (5 & ~7Hz) for a range of contrast combinations. With no free parameters, the model predicted several key findings in the complex pattern of contrast response functions that were observed empirically in both stimulus domains: (i) there is little increase in the response when a second component is added, especially at high contrasts, (ii) under specific conditions, increasing the contrast of one stimulus can reduce the overall response (analogous to Fechner's paradox), (iii) when components flicker at different frequencies, a high contrast 'mask' component shifts the contrast response function to the right, (iv) when components increase in contrast together, the contrast response function is twice as steep for same frequency flicker as for different frequency flicker. The accuracy of these predictions is surprising, as the model was derived to explain data from psychophysical (contrast discrimination) experiments, with no expectation that it should generalise to other experimental paradigms. That it does so suggests that psychophysical methods are informative regarding the activity of large populations of neurons, and that the general combination model provides a good account of signal interactions across multiple dimensions.

56.406 Evidence for aspect-ratio processing independent of the linear dimensions of a shape: A channel-based system

David Badcock[1](david.badcock@uwa.edu.au), Sarah Morgan[1], Edwin Dickinson[1]; [1]Human Vision Laboratory, School of Psychology, The University of Western Australia

Aspect-ratio (height:width ratio) is a fundamental property for shape discrimination. Aspect-ratio might be detected by combining separate estimates of height and width, or by a specialized aspect-ratio detector sensitive to height:width ratios independently from separate linear dimensions. Previous work suggests aspect ratio is the primary cue. The current study further tested these two hypotheses for aspect-ratio detection by measuring size (2D area) aftereffects and aspect-ratio aftereffects. In a novel procedure, employing forced-choice psychophysical methods, the size aftereffects were used to predict an aspect-ratio aftereffect consistent with the height-and-width-combination hypothesis, which was opposite in direction to that predicted by the specialized aspect-ratio detector hypothesis. This was possible because a preliminary experiment, using square stimuli, showed size aftereffects exhibit a non-monotonic relationship to adaptor:test size ratios. The results showed that the direction of the aspect-ratio aftereffect was consistent with the specialized aspect-ratio detector hypothesis. In an extension of this study aspect-ratio aftereffects were then measured, for a large range of adaptor:test ratios, to determine whether this specialized detector represents aspect-ratio using a multi-channel or opponent coding system. The results showed smaller after effects with large adaptor:test ratios than with intermediate ratios. This outcome is consistent with multi-channel coding, i.e. that aspect-ratio is detected by multiple mechanisms sensitive to small, overlapping ranges of aspect-ratio.

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56.407 Using maximum likelihood difference scaling to measure visual discomfort

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Visual discomfort describes the adverse effects, such as headaches, eyestrain and illusions, that can be experienced when viewing some visual patterns. The ability to measure discomfort reliably has many important applications, for example in the development of three-dimensional displays, and the understanding of migraine. Previous research has used a variety of methods, including rating scales, to measure discomfort. Typically, an observer is presented with a stimulus and asked to judge (e.g. on a scale of 1 to 10) the degree of discomfort experienced. One limitation of such techniques is that there is an unknown mapping between the experience of discomfort, and the scale values reported. In the current study, we assessed whether maximum likelihood difference scaling (MLDS) could be used to quantify discomfort. In the first experiment, observers were presented with simple Op Art pictures, and asked firstly to judge whether they were uncomfortable, and secondly to quantify the degree of discomfort. In the second experiment, observers were presented with pairs of pairs of these stimuli. They were asked to judge which pair was more similar in (i) spatial frequency and (ii) discomfort. Their responses were used to create perceptual scales for spatial frequency and discomfort using MLDS. In the first experiment, discomfort depended on spatial frequency. In the second experiment, when asked to base judgements on perceived spatial frequency, MLDS uncovered a perceptual scale that varied with the log of spatial frequency. However, when asked to base judgements on perceived discomfort, 5 of the 8 observers failed to consistently carry out the task. These results show that observers are readily able to separate judgements of discomfort from judgements of other stimulus dimensions (in this case spatial frequency), but that the measurement of visual discomfort presents a significant challenge to MLDS.

56.408 Stable individual distortions in the perceived locations of static stimuli

Anna Kosovicheva[1](anko@berkeley.edu), David Whitney[1]; [1]Department of Psychology, University of California, Berkeley

The ability to make fine localization judgments is crucial for interaction with objects in our environment. Although retinotopic representations of object locations are an important component of stimulus localization, a large body of work has shown that other factors, such as motion, attention, and frames of reference play an important role as well. While previous studies have described how these factors influence perceived locations across groups of observers, individual differences in perceptual localization remain poorly understood. In the present study, we performed a series of experiments to map individual differences in perceived position. On each trial, subjects were shown a 50 ms random dot noise pattern

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within a Gaussian contrast envelope. Angular stimulus position varied randomly along a 7 degree invisible isoeccentric ring. Subjects reported the target's position by adjusting a cursor to its location. We found that subjects demonstrate idiosyncratic patterns of response error (up to 10-15° of rotation angle at a single location) and that these patterns are stable across multiple testing sessions. Correlations of mean response error across the set of stimulus locations were high across testing sessions within each subject (r = .63), but low between subjects (r = -.03). We also demonstrated that these patterns were robust to changes in response method, as subjects' errors in the adjustment task correlated with those in a separate 2AFC task in which subjects compared the positions of stimuli across two intervals (r = .66). Finally, we demonstrate that perceived position correlated with subjects' saccade errors as they made speeded saccades to the same targets. Together, our results provide novel evidence for stable idiosyncratic patterns of perceptual distortions across observers and demonstrate the importance of measuring individual differences in perceived location.

56.409 **Not all Distortions are Created Equally: The Visibility of Image Artifacts with Application to Image Quality** Elyse H. Norton[1](ehn222@nyu.edu), Michael S. Landy[1, 2], Eero P. Simoncelli[2, 3, 4]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University, [3]Courant Institute of Mathematical Sciences, New York University, [4]Howard Hughes Medical Institute

Quantifying the visibility of distortions in photographic images is of fundamental importance in many fields. The most commonly used error measure, root-mean-squared error (RMSE), is a poor predictor of perceived image quality, because the visibility of a given distortion is critically dependent on its spatial structure and its relationship to the underlying image. Specifically, some patterns of distortion affect perceived image quality less because they are masked by the image content. Wang and Simoncelli (IEEE Proc. ICIP, 2005) proposed a metric based on a weighted sum of squared differences in which a family of image-dependent distortion components receives smaller weights than other components. These image-dependent components are derived from the image content as linear approximations to naturally-occurring distortions, such as spatial translations and changes in mean luminance or contrast. Here, we introduce a psychophysical method to estimate the appropriate weights for these image-dependent distortion components. Stimuli consisted of natural images, and distorted versions generated for each image-dependent component, D (e.g., horizontal translation), each possible weight, wD, for that distortion, and one of a fixed set of RMSE values. Distorted images were generated that maximized image quality according to the metric (using wD) for each fixed RMSE value. Observers were required to detect the distorted version in a 3-interval forced-choice task (two copies of the original and one distorted image). Detection thresholds were measured as a function of RMSE for each D and wD. We predicted, and indeed found, that RMSE detection thresholds obey an inverse-U-shaped function of wD. The peak of this curve occurs at a value of wD for which observers are least sensitive to these quality-metric-minimizing distortions, providing an optimal value for wD. Thus, our technique may be used to tune the image quality metric to reflect human sensitivity to image distortion.

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56.410 **A computational model of the Münsterberg (Café wall) illusion and related phenomena** Dejan Todorović[1](dtodorov@f.bg.ac.rs); [1]Laboratory of Experimental Psychology, Department of Psychology, University of Belgrade, Serbia

The Münsterberg (Café wall) illusion belongs to a class of illusions of tilt whose effectiveness crucially depends on the luminance polarities of the elements of the displays. A computational model of such phenomena was constructed, in the form of a network of units which simulate simple cells in V1. The receptive fields of the units were modeled as Gabor functions or as differences of shifted Gaussians, with different sizes and orientations. Inputs for the model were matrices of 32x32 units arranged on a 2D grid, representing various visual stimuli, and outputs were 32x32 matrices of reactions of network units to the stimuli. The model was tested with two classes of 'control' stimuli and two classes of 'experimental' stimuli. One class of control stimuli consisted of simple displays which did not contain tilted elements (such as normally oriented checker-board type patterns), and which did not evoke percepts of tilt from horizontal or vertical; the other class consisted of related displays which did contain tilted elements (tilted or sheared checker-board patterns) and did evoke percepts of tilt. The experimental stimuli were various standard and novel variants of the Café wall configuration and configurations devised by Akiyoshi Kitaoka (such as the 'enhanced checkered illusion'), one class of which evoked strong percepts of tilt, and the other class which generally did not evoke such percepts. The main finding was that the displays that evoked impressions of tilt, whether real (control stimuli) or illusory (experimental stimuli), exhibited similar signature patterns along edges in the simulation outputs, involving characteristic shifted local activity profiles. In contrast, displays that did not evoke tilt impressions lacked such patterns. The conclusion is that the reason that illusory tilt is evoked by this class of displays is that they cause neural activity distributions similar to those caused by actually tilted displays.

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56.411 **Contrast gain control in plaid pattern detection** Pi-Chun Huang[1](pichun_huang@mail.ncku.edu.tw), Yu-Shen Huang[1], Chien-Chung Chen[2]; [1]Department of Psychology, National Cheng-Kung University, Tainan, Taiwan., [2]Department of Psychology, National Taiwan University, Taipei, Taiwan.

A controversy remains in the literature on the visual mechanisms underlying the detection of a plaid pattern. One theory suggested the detection was mediated by a plaid selective mechanism while the other, a combination of two oriented channels with contrast gain control. Here, we used a pattern masking paradigm to investigate this issue. The target was either a spiral plaid or a spiral grating on a spiral plaid or a spiral grating (in either parallel or orthogonal orientation to the grating target) pedestal. A temporal 2AFC with staircase method was used to measure the discrimination thresholds of the target at 7 pedestal contrasts. All conditions, except the one with orthogonal target and pedestal gratings, showed a typical dipper shape target threshold vs. pedestal contrast (TvC) functions. That is, the threshold first decreased (facilitation) and then increased (suppression) with pedestal contrast. TvC function for grating-on-grating and plaid-on-plaid conditions overlaped at high pedestal contrasts. The TvC function shifted upward for the grating-on-plaid condition. The plaid-on-grating condition showed a weaker facilitative and suppressive effects than the plaid-on-plaid conditions. We fitted the data with versions of the divisive inhibition model, where the facilitative input was divided by the sum of broadband inhibitory inputs, to test whether our result can be accounted for by a filter specific for plaid or by a combination of two orthogonally oriented filters. The latter model described the data better with fewer free parameters. We conclude that plaid detection is mediated by a combination of two contrast gain control mechanisms with receptive fields whose orientation are orthogonal to each other.

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56.412 **Serial Dependence of Position Perception** Alina Liberman[1](alinal@berkeley.edu), Anna Kosovicheva[2], David Whitney[1,2]; [1]Helen Wills Neuroscience Institute, UC Berkeley, [2]Dept. of Psychology, UC Berkeley

Observers perceive objects in the world as stable over space and time, even though visual experience with those objects is often discontinuous and distorted due to eye movements, occlusion, and visual noise. How are we able to easily and quickly achieve stable perception in spite of this constantly changing visual input? Prior work has shown that perception of orientation at the present moment is attracted towards attended orientations seen up to 15 seconds back in time (Fischer, Shankey, and Whitney, VSS, 2011), and that this serial dependence effect extends to face identity perception (Liberman, Fischer, and Whitney, VSS, 2012). Serial dependence is therefore a potential mechanism for maintaining perceptual stability of objects in the world. Here, we asked whether the visual system utilizes an object's prior physical location to inform future positions, since this would maximize location stability of an object over time. To test this, we briefly presented subjects with 3-degree grating patches at random angular locations relative to central fixation at an eccentricity of 10 degrees of visual angle. Subjects reported the perceived location of the gratings on each trial by adjusting a cursor's position to match the location of the previous grating. Subjects made consistent errors when reporting the perceived location of the grating on the current trial, mislocalizing it toward the location presented on the previous two trials. Furthermore, this pull in position perception also occurred when a response was not required on the previous trial, indicating this was not a general bias due to subject responses. Therefore, serial dependence does seem to occur for position representations, which could contribute to the stable perception of objects in space.

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56.413 A neural model of distance-dependent percept of object size constancy

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Size constancy is one of the well-known perceptual phenomena that demonstrates perceptual stability to account for the effect of viewing distance on retinal image size. Although theories involving distance scaling to achieve size constancy have flourished based on psychophysical studies, its underlying neural mechanisms remain unclear. Recently, single cell recordings show that distance-dependent size tuned cells are common along the ventral stream, originating from V1, V2, and V4 leading to IT (Dobbins et al., 1998). In addition, fMRI studies demonstrate that an object's perceived size, associated with its perceived egocentric distance, modulates its retinotopic representation in V1 (Murray et al., 2006; Sperandio et al., 2012). These results suggest that V1 contributes to size constancy, and its activity is possibly regulated by feedback of distance information from other brain areas. Here, we propose a neural model based on these findings. A population of gain-modulated MT neurons integrate horizontal disparity (arising from V1) and vergence (arising from FEF) to construct a three-dimensional spatial representation in area LIP. Disparity selective cells in V1 are gain-modulated and simulated by gaussian functions, vergence selective cells in FEF are simulated by sigmoidal functions. Cells in MT integrate the outputs both from V1 and FEF cells by means of a set of basis functions; the outputs of MT cells feed forward to cells in LIP to construct a distance map. The LIP neurons send feedback of distance information to MT to obtain a distance scaling function, and then further back to V1 to modulate the activity of size tuned cells, resulting a spread of V1 cortical activity. This process provides V1 with distance-dependent size representations. The model supports that size constancy is preserved by scaling retinal image size to compensate for changes in perceived distance, and suggests a neural circuit capable of implementing this process.

56.414 Optimal retinal population coding predicts inhomogeneous light adaptation and contrast sensitivity across the visual field

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Spatial contrast sensitivity varies with ambient light levels and eccentricity (Shapley and Enroth-Cugell, 1984) and is thought to be largely determined by the retinal code. Light adaptation of contrast sensitivity was previously shown to match theoretical predictions of efficient coding in the retina (Atick & Redlich, 1990; van Hateren, 1992). However, the actual adaptive change is more complicated and depends on both light adaptation and visual eccentricity (Koenderink et al., 1978). Here, we show these phenomena can be predicted from the same theoretical principle. Specifically, we employ a generalized model of optimal neural coding that, unlike previous models, can be optimized for any number of neurons relative to the input dimension and counteracts inherent noise and signal degradation (Doi and Lewicki, 2011). We model 1) optical blurring and photoreceptor noise, 2) the local convergence from cone photoreceptors to retinal ganglion cells (RGCs) which varies dramatically with eccentricity (Goodchild et al., 1996; Ahmad et al., 2003), and 3) the limited neural capacity of RGCs (Borst and Theunissen, 1999). We find that the adaptive change of model RGC receptive fields is larger at the fovea as in the previous studies, but becomes progressively smaller in the periphery. This is consistent with available neural data (Barlow et al., 1957; Enroth-Cugell and Robson, 1966), although experimental data in the fovea, where the predicted change is greatest, is lacking. Finally, we show that the optimal retinal code can be used to predict psychophysical light adaptation and contrast sensitivity and is consistent with experimental data at the fovea and different eccentricities (Koenderink et al., 1978).

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56.415 A Unified Computational Model of Primary Visual Cortex: Consolidation of the Scattered Literature on Simple and Complex Cells

Tadamasa Sawada[1](tada.masa.sawada@gmail.com), Alexander A. Petrov[1]; [1]Department of Psychology, the Ohio State University

The response properties of neurons in V1 have been explored in many empirical studies and modeled in quantitative detail. However, the data are scattered across dozens of articles and the models employ idiosyncratic parameterization schemes tailored to fit specific data sets. Here we consolidate the fragmented results of the prior studies in terms of a unified model. The model takes static grayscale images as inputs and represents them as firing-rate patterns across a population of simple- and complex-cell-like units tuned for orientations and spatial frequencies. Divisive normalization (Heeger, 1992) accounts for surround suppression, cross-orientation and cross-frequency suppression, and various contrast and pedestal effects. The model parameters are specified in terms of a calibration procedure that makes them implementation-independent and facilitates the inclusion of the model into larger integrated systems. The model is tested on stimuli from 18 representative neurophysiological experiments, including gratings, gabors, and plaids of various sizes, contrasts, orientations, and spatial frequencies. All fits use a common set of parameter values. The properties of units (or channels) in the model agree qualitatively and often quantitatively with the properties of simple and complex V1 cells in monkeys and cats. Moreover, the model gives parameter-free accounts of some phenomena that have not been modeled in detail before. Whereas basic properties such as orientation tuning are built into the model by design, complex properties emerge from the interactions of multiple mechanisms. For example, high-contrast gratings of sub-optimal orientation produce more surround suppression compared to optimal low-contrast gratings both empirically (Tailby, Solomon, Peirce, & Metha, 2007) and in the model. Such emergent properties can only be explained in an integrated model. Last but not least, the model can be used as an off-the-shelf building block of larger models, with default parameters that are consistent with neurophysiological measurements.

Acknowledgement: NIH

Visual search: Eye movements

Tuesday, May 20, 2:45 - 6:45 pm

Poster Session, Banyan Breezeway

56.416 Searching for overlapping objects in depth: Depth speeds search, but does not improve response accuracy

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Using a visual search task, we examined the combined effects of overlap and three-dimensional depth on search performance. Participants searched through displays containing opaque polygon targets while their eye-movements were recorded. Half of the participants searched displays with objects presented at different depth planes to one another (the 'multi-plane' condition) and the other half of the participants searched displays with objects presented at a single depth plane (the 'single-plane' condition). As the degree of overlap between objects increased, both RTs and error rates also increased. RTs and error rates were particularly affected when more than two objects could overlap. Adding stereoscopic depth to the images enabled participants to respond more rapidly, though not more accurately, when the level of overlap was high. Eye movement analyses showed a similar pattern for overlap, with increasing fixation durations, increasing number of fixations, and increasing total fixation time as the level of overlap increased. Stereoscopic depth reduced the total time spent fixating regions containing many overlapping objects, suggesting that depth aided in object segmentation and recognition processes. These results have implications both for current models of visual search, which have not yet explored the role that overlap and depth together can play in modulating search behaviour, and for real-world search tasks that contain overlapping objects, such as airport X-ray screening and radiography.

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56.417 You don't know where your eyes have been and that could be problem.

Jeremy Wolfe[1,2](wolfe@search.bwh.harvard.edu), Trafton Drew[1,2], Melissa Vo[1,2]; [1]Visual Attention Lab, Brigham and Women's Hospital, [2]Harvard Medical School

Hidden formatting deleted. Delete this text! text-autospace:none">When you can't find your keys and you swear that you have "looked everywhere", you probably haven't. We tracked the eyes of 24 radiologists searching through chest CT scans for small white nodules that are signs of lung cancer. They searched by scrolling up and down through the volume of the chest for up to 3 minutes. Many radiologists finished early, presumably satisfied that they had adequately examined the entire lung. They found 57% of the nodules, but did they "look everywhere"? To estimate coverage, we assumed a circular Functional Visual Field (FVF) around the point of fixation in the current slice. Coverage depends on estimates of FVF radius. A 2.5 deg FVF results in 41% estimated coverage. This rises only to 68% with a generous 5 deg field. It is not clear that one could resolve lung nodules 2.5 deg away from fixation and eye tracking suggests that many nodules were never adequately fixated. Didn't our radiologists know that they had failed to look at large parts of the stimulus? Maybe not. In Exp2, naïve Os performed an easy change detection task. They looked at pairs of scenes

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for 3sec each, attempting to detect a change in Scene2. On 25% of trials, Scene2 was replaced by a request to make 12 mouse clicks on locations in the unchanged Scene1 "where you think you just fixated". After 135 trials, observers saw 10 new scenes and were asked to put 12 clicks where "someone else would have looked". Observers' memory for the placement of their own fixations was no better than another observer's guesses. While we have some understanding of where people should look or where fixations are likely, we seem to have a very poor record of where we actually just looked.

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56.418 **Comparing search strategy in breast tomosynthesis and 2D mammogram: an eye tracking study** Avi Aizenman[1](Aizenman.Avi@gmail.com), Trafton Drew[1,2], Dianne Georgian-Smith[1], Jeremy M. Wolfe[1,2]; [1]Brigham and Women's Hospital, [2]Harvard Medical School

Breast cancer screening (mammography) has typically involved search of 2D x-rays of the breast. A new modality, breast tomosynthesis (BT) allows visualization of a series of slices through the breast, reducing occlusion from overlapping tissue. BT appears to improve performance but, because it is new, little is known about best search strategies and nothing is known about eye movements during BT search. We compared eye movements for eleven radiologist examining eight BT and and 2D cases. Four cases in each modality contained abnormalities. Each showed only one breast. Observers marked suspicious masses with mouseclicks. Eye-position in X/Y space was recorded at 1000Hz and co-registered with slice/depth plane as radiologists scrolled through BT images, allowing a 3D representation of eye position. As in previous work, BT hit rate for masses was higher than for 2D cases. BT false alarm rate was lower. However, BT search durations were much longer (75s) than 2D (43s). Tomosynthesis produced longer fixations and less distance travelled per unit of time by the eyes. Our lab has shown that, when searching through volumetric images of the chest, radiologists typically adopt one of two distinct strategies. "Drillers" scroll quickly through depth while keeping XY eye position relatively constant. "Scanners" carefully search each XY depth plane before scrolling more slowly in Z (Drew et al., 2013). Mammographers in the current study appear to be predominantly drillers. However, there was some variability in how consistently they used this strategy and how often they made large scanning eye-movements in the XY plane. The current study is a first step towards assessing the effectiveness of different search strategies in tomosynthesis.

Acknowledgement: NIH-EY017001, Toshiba

56.419 **Visual search and the power spectra of radiological scans** Elysse Kompaniez[1](kompaniez@aol.com), Craig K. Abbey[2,4], John M. Boone[3,4], Michael A. Webster[1]; [1]Psychology, University of Nevada, Reno, [2]Psychology, University of California, Santa Barbara, [3]Biomedical Engineering, University of California, Davis, [4]Radiology, University of California, Davis

Adaptation to radiological images produces strong aftereffects in the perceived texture of images. For example, prior exposure to mammograms classified as dense or fatty tissue causes intermediate images to appear more fatty or dense, respectively. Previously (Kompaniez et al. VSS 2013) we found that these texture aftereffects can also impact performance on the types of visual detection tasks confronting radiologists: finding a simulated lesion within the image. Observers were faster finding targets (Gaussian spots) when they were first adapted to the type of image (dense or fatty) on which they were searching. In the present study we tested for analogous effects on search when adapting instead to the characteristic power spectra of mammograms. These spectra are steeper (slopes ~-3) than that of natural stimuli (~-2), and we showed previously that adaptation to them produces corresponding aftereffects in perceived blur. For the search task, observers first adapted for 5 min to a series of image sections taken from scans of normal tissue, shown either with the original spectrum or filtered to a "natural" spectrum with a slope of -2 (with rms contrast equated). They then searched for a target within either the unfiltered or sharpened images. Targets were again simulated lesions corresponding to bright Gaussian spots (sd = .18 deg), superimposed by adding the luminance to the background. Unlike the effects for texture, in this case reaction times were unaffected by the adaptation. Moreover, mean search times remained similar on the original or filtered backgrounds, even though the latter simulate theoretically complete adaptation to the power spectra. These results suggest that the search improvements with texture adaptation are not a generic consequence of prior exposure to the images, and may reflect greater selectivity of the adaptation for the phase vs. amplitude differences distinguishing the backgrounds from each other or the targets.

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56.420 **Infant and Adult Localization of a Conjunction Target: An Eye Movement Study** Scott Adler[1](adler@yorku.ca), Christina Fuda[1], Audrey Wong Kee You[1]; [1]Department of Psychology and Centre for Vision Research, York University

Visual search studies have shown that 3-month-olds exhibit "pop out" and asymmetries in the localization of feature-present versus feature-absent targets similar to adults (Adler & Orprecio, 2006; Adler & Gallego, revision under review). Research, however, has suggested that infants do not accomplish a conjunction search until around 6 months of age (Bhatt, Bertin & Gilbert, 1999). Previous conjunction search research with infants, however, has assessed their behavior using habituation and preferential looking paradigms, which measure performance in seconds rather than milliseconds as is the case in studies of adults' search. To allow for direct comparison of the two ages and comparable assessment of the relative development of search and attentional mechanisms, this study measured infant and adult saccadic latencies in milliseconds to localize both conjunction and feature targets. Infants and adults were presented with arrays of 3 different set sizes (5, 8, 10), each consisting of a unique target (a green or red "X" or "O") being either present or absent. Surrounding distractors differed based on a single unique feature (shape or color) or a conjunction of features (shape and color) relative to the target. Results indicated that both infants' and adults' saccadic latencies exhibited relatively flat functions across set sizes in localizing the feature target. In localizaing the conjunction target, in contrast, adults' saccadic latencies increased as a function of set size, whereas infants' latencies did not increase with set size. Infants' latencies were also approximately 200 msec slower than adults' in the conjunction search. These results, consistent with previous studies, suggest a developmental progression in the availability of top-down mechanisms, with young infants relying solely on bottom-up processing of stimulus properties such as the saliency of the target. Adults, in contrast can use top-down mechanisms to facilitate their localization of the conjunction target.

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56.421 **Immediate Feedback During Multiple-Target Visual Search Improves Accuracy** Nada Attar[1](nada_h_a@yahoo.com), Chia-Chien Wu[1], Marc Pomplun[1]; [1]Department of Computer Science, University of Massachusetts Boston

Visual search is one of the most common behaviors in daily life. Studies of visual search, however, mainly focus on how physical properties of stimuli affect search efficiency. The current study examined the effects of immediate auditory feedback for each selection during a multiple-target visual search task. Each search display contained 32 Gabor patches, two to five of which were designated as search targets by their specific tilt angle. The subjects' task was to press a key whenever they found a target, and they heard a sound immediately after each key press. In the feedback condition, one of two different sounds was played, indicating whether the subject had reported a correct detection, i.e., was fixating a target. In the no-feedback condition, subjects always received a neutral sound, regardless of whether they had visually selected a target or a distractor. A trial was finished when subjects pressed another key to indicate that they had found all targets. We analyzed overall performance measures such as trial duration and the proportions of correct target detections and correctly completed trials. Furthermore, we analyzed pupil size as a measure of cognitive effort. Additional analyses compared pupil size and basic eye-movement variables such as fixation duration and saccade amplitude between the experimental conditions and across different types of gaze transitions. The results show that pupil dilation and search accuracy were greater when subjects were given feedback than when they only received a neutral sound. The time to complete a trial, on the other hand, was longer in the feedback condition, even though subjects detected the next target faster after receiving positive feedback as compared to a neutral sound. In summary, the present study demonstrates that immediate feedback increases cognitive effort, leading to more accurate but overall slower search, with enhancement of specific components of search behavior.

56.422 **Revealing the dynamics of visual masking using a speeded saccadic choice task** Sébastien M. Crouzet[1](seb.crouzet@gmail.com), Simon Hviid Del Pin[2], Morten Overgaard[2,3], Niko A. Busch[1,4]; [1]Institute of Medical Psychology, Charité University Medicine, Berlin, Germany, [2]CCN, Dept. of Communication and Psychology, Aalborg University, Denmark, [3]CNRU, CFIN, MindLab, Aarhus University, Denmark, [4]Berlin School of Mind and Brain, Humboldt-University, Germany

Object substitution masking (OSM) occurs when a briefly presented target in a search array is surrounded by small dots that remain visible after the target disappears. The reduction of target visibility occurring after OSM has been suggested to result from a specific interference with reentrant visual processing. Here, we tested a prediction derived from this hypothesis: responses fast enough to have been triggered before the beginning of reentrant processing should escape this interference, and thus not be affected by masking. To this aim, we combined an OSM paradigm with a saccadic choice task, in which the fastest saccades occur as early as 120 ms after target onset, allowing to study the effect of masking at an early phase of visual processing. In the first experiment, we manipulated target visibility using either OSM, backward masking, or low stimulus contrast and compared their effect on accuracy over time. A general reduction of performance was observed in all three conditions. The analysis of accuracy as a function of response time revealed that the fastest saccades (120-150 ms time-window) were virtually unaffected by both OSM and backward masking, while performance was strongly reduced for saccades slower than 150 ms. This RT-dependent performance impairment was specific to the masking procedures, since the control condition in which performance was impaired through a contrast decrease showed no such difference between fast and slow saccades. The second experiment with additional EEG recordings revealed that pre-stimulus alpha band activity influences the accuracy of the saccade to come, especially for the fastest responses. These findings provide further evidence that masking interferes mostly with reentrant processing, while leaving early feedforward processing largely intact, and bring new insights into the trial-to-trial variability of reaction times and accuracy.

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56.423 **Efficient saccade planning requires time and clear choices.** Saeideh Ghahghaei[1](saeideh@ski.org), Preeti Verghese[1]; [1]The Smith-Kettleweel Eye research Institute

We move our eyes constantly to gather information. Saccades are efficient when they maximize the information required for the task, but evidence for efficient saccade planning is mixed. For example, eye movements are efficient when searching for a single target (Najemnik & Geisler, 2005), but are inefficient when searching for an unknown number of targets in noise, particularly under time pressure (Verghese, 2012). Here we examine whether saccades can be made more efficient by increasing the discriminability of target vs. distractor as well as by delaying the first saccade, so that decision processes can influence saccade planning. Methods: Observers actively searched a brief display (900 ms) with six Gabor patches to locate an unknown number of horizontal patches, among vertical distractor patches. Noise was added to the patches, making target /distractor identity harder to discern without a saccade to the patch. Each location had an independent probability of target, so the number of targets in a trial ranged from 0 to 6. We varied the prior probability of the target occurring at each location, from low to high in separate blocks. When the prior is high a saccade strategy that selects the noisy (uncertain) patches is more efficient. In separate experiments we 1) removed the noise from 50% of the patches to improve target-distractor discriminability and 2) delayed the first saccade to determine whether a longer inspection time would allow decision processes to influence saccade strategy. Results: A trial-by-trial analysis of observers' saccades showed that when there was a discernible difference between clear and noisy patches, observers moved their eyes to the noisy patches to maximize information gained. Furthermore, this preference for uncertain locations was even more pronounced when the first saccade was delayed. Conclusion: Decision processes can influence longer latency saccade choices when the choices are clear.

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56.424 **First saccadic eye movement reveals persistent attentional guidance by implicit learning** Bo-Yeong Won[1,2](wonxx039@umn.edu), Khena Swallow[3], Yuhong Jiang[1,2]; [1]Department of Psychology, University of Minnesota, [2]Center for Cognitive Sciences, University of Minnesota, [3]Department of Psychology, Cornell University

Implicit learning about where a visual search target is likely to appear often speeds up search. However, whether implicit learning guides spatial attention or affects post-search decisional processes remains controversial. Using eye tracking, this study provides compelling evidence that implicit learning guides attention. In a training phase, participants often found the target in a high-frequency, "rich" quadrant of the display. When subsequently tested in a phase during which the target was randomly located, participants were twice as likely to direct the first saccadic eye movement to the previously rich quadrant than to any of the sparse quadrants. The attentional bias persisted for nearly 200 trials after training and was unabated by explicit instructions to distribute attention evenly. We propose that implicit learning guides spatial attention but in a qualitatively different manner than goal-driven attention.

56.425 **Spatial dependency of objects, but not scene gist contributes semantic guidance of attention** Chia-Chien Wu[1](chiachie@cs.umb.edu), Hsueh-Cheng Wang[2], Marc Pomplun[1]; [1]Department of Computer Science, University of Massachusetts at Boston, [2]Computer Science and Arti cial Intelligence Laboratory, Massachusetts Institute of Technology

Previous studies (Hwang et al., 2011; Wu et al., 2013) have shown that, during natural scene viewing, observers' gaze transitions are biased towards objects that are semantically similar to the currently fixated one, and this bias does not disappear even when the information about scene gist is removed from the scene. This result, however, does not explain the role of scene gist and how it may interact with spatial dependency among objects. To answer these questions, subjects were asked to view displays in which the presence of scene gist and spatial dependency was varied. Each display was generated by segregating 15 objects from a natural scene in the LabelMe database and pasting them on a grey canvas. To vary spatial dependency, the objects were placed either at the same coordinates as in the original scene (fixed condition), or at randomly selected locations on the canvas (scrambled condition). In the fixed condition, scene gist information was either eliminated or provided by either previewing the original scene for 80 msec, or showing the original scene with all 15 selected objects being marked and subjects being asked to only focus on these objects. The results show that, without scene gist, spatial dependency among objects can still induce semantic guidance, and this effect did not disappear even for saccade amplitudes of up to 16°. Interestingly, the effect of semantic guidance was not affected by providing scene gist information, and it disappeared only when spatial dependency was eliminated. Our results imply that observers mainly use spatial dependency among objects but not scene gist to infer semantic information from the scene and guide their attention. Extracting semantic information simply based on spatial dependency may be an efficient strategy that only adds little cognitive load to the viewing task.

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56.426 **The role of context in visual search in immersive environments.** M. Pilar Aivar[1](mariapilar.aivar@uam.es), Chia-Ling Li[2], Dmitry Kit[3], Matthew H. Tong[4], Mary M. Hayhoe[4]; [1]Facultad de Psicología, Universidad Autónoma de Madrid, [2]The Institute of Neuroscience, University of Texas at Austin, [3]University of Bath, [4]Center for Perceptual Systems, University of Texas Austin

Contextual Cueing experiments have shown that subjects learn the relationship between a target object and the context when the context is predictive of target location. Implicit learning of context is thought to facilitate search for objects embedded in complex displays. However it is unclear if cueing effects generalize to natural situations. We therefore performed a visual search task in an immersive virtual apartment with two rooms, linked by a corridor. Participants searched for a series of geometric target objects while eye movements were recorded. On each trial an object was presented on a screen placed in the corridor. Participants explored the two rooms until they located it. Context was manipulated by presenting three kinds of target objects. To evaluate the role of global context we compared Stable objects (that always appeared at the same location) with Random objects (that appeared at a new location in each trial). To examine the role of local context we presented Paired objects in close proximity: one object of the pair was the target during the first phase of the experiment while the other became the target later on. Objects not currently search targets were not visible, to avoid incidental learning for targets. We found that search time and number of fixations to locate the target decreased with repeated search episodes for all objects, but more so for stable objects, indicating that memory for the spatial location of the object is more important than memory for global context. However, for the Paired objects there was little advantage of experience in locating the neighboring object, which suggests that local context is not encoded in memory during previous search trials. Thus the role of contextual cueing in search in naturalistic environments appears to be weak relative to the role of spatial memory for previous search targets.

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56.427 **Visual similarity is stronger than semantic similarity in guiding visual search for numbers** Tamaryn Menneer[1](t.menneer@soton.ac.uk), Hayward, J. Godwin[1], Michael, C. Hout[2]; [1]Centre for Vision and Cognition, Psychology, University of Southampton, UK, [2]Department of Psychology, New Mexico State University, USA

The consideration of semantic information is becoming increasingly important in visual search and models of search (Wolfe, Võ, Evans & Greene, 2011), particularly in search of scenes, in which target semantics and scene context influence the location of eye fixations (e.g., Oliva & Torralba, 2007). With more abstract stimuli, search for the number 5 amongst distractor digits is slower and less accurate when distractors are semantically close numbers (3, 4, 6, 7) compared with distant numbers (1, 2, 8, 9) (Schwarz & Eiselt, 2012). The aim of the current experiment was to extend this previous study to assess the influence of visual similarity as well as semantic similarity in number search. Eye movements were recorded while participants searched for a target digit amongst other digits (e.g., 0 amongst 1-9). We examined the probability of fixating the various distractors as a function of two key dimensions: the visual similarity between the target and each distractor, and the semantic similarity (numerical distance) between the target and each distractor. A key requirement of this research was to quantify visual similarity, which was achieved using multidimensional scaling (MDS) of independent observer similarity ratings. The probability of fixating distractors was driven by both visual and the semantic similarity. However, in some contrast to previous findings, visual similarity played a larger role than semantic similarity in guiding search. These findings contribute to the growing literature of the relative importance of semantic and visual information in visual search, as well as providing a proof of concept for the usefulness of MDS as a tool for such studies.

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56.428 **Using Eye Movements to Investigate Individual Differences in Linguistically Mediated Visual Search** Sankalita Mandal[1](rini.sankalita@gmail.com), Tandra Ghose[1], Yannik T. H. Schelske[1], Eric Chiu[2], Michael J. Spivey[2]; [1]University of Kaiserslautern, Germany, [2]University of California, Merced, USA

In traditional visual-search, the search-time is strongly affected by the number of distractors when the target is defined by a conjunction of features but not for targets defined by single features. In Linguistically-Mediated Visual-Search (LMVS) it has been demonstrated that the search-time in conjunction search can be made less dependent on the number of distractors by incremental spoken delivery of target features (e.g. "Is there a red vertical?") but not when the audio cue completely preceded the visual display. The former condition is called Audio/Visual-Concurrent (A/V-Concurrent) and the later Auditory-Preceding (A- Preceding). However, previous research found that the efficiency of conjunction search improved for majority of participants but not for all of them. Here we use the paradigm of Spivey et al. (2001) and additionally recorded eye-movements. 30 observers participated in a 96 trial experiment with equal number of target-present and target-absent trials and set sizes of 5, 10, 15, and 20. Both A- Preceding and A/V-Concurrent conditions used speech files with "Is there a..." spliced onto the beginning of each of the four target queries and two descriptive adjectives (color: "red" or "green" and orientation: "vertical" or "horizontal"). 17 participants showed the expected LMVS effect with slope_Precedingslope_Concurrent (13.2, 11.5, p=0.5). The analysis of eye-movement reaction-time (EM-RT), measured by the first fixation close to the target, showed that there was no significant difference in the two conditions for the former group but the slope_EM-RT_Concurrent>slope_EM-RT_Preceding (34.2,12.6,p<.05) for participants not showing the LMVS effect. We demonstrate that the individual differences in LMVS effects can be explained by analysis of EM_RT which indicates that some participants may not integrate audio and visual information online to improve the efficiency of conjunction search.

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56.429 **Disruption of spatial but not of temporal object continuity impairs transsaccadic learning: Evidence from visual search** Katharina Weiß[1](katharina.weiss@uni-bielefeld.de), Werner X. Schneider[1], Arvid Herwig[1]; [1]Department of Psychology and Cluster of Excellence "Cognitive Interaction Technology," Bielefeld University

Contradicting subjective visual experience, spatial processing resolution of a particular object in the visual field can differ considerably due to eye movements. The same object will be represented with high acuity in the fovea but only coarsely in periphery. Herwig and Schneider (submitted) proposed that the visual system counteracts such transsaccadic resolution differences by predicting — based on previous experience — how foveal objects will look like in the periphery and vice versa. They demonstrated that previously learned transsaccadic associations between peripheral and foveal object information facilitate performance in visual search — irrespective of the correctness of these associations. False associations were learned by replacing the pre-saccadic object by a slightly different object during the saccade. Importantly, participants usually did not notice this object change. This raises the question whether perception of object continuity is a critical factor in building of transsaccadic associations. Therefore, we modified the paradigm of Herwig and Schneider to disturb object continuity during transsaccadic learning by a post-saccadic blank (Experiment 1) or by a task-irrelevant shape change (Experiment 2). Surprisingly, transsaccadic learning could not be prevented by disruption of temporal object continuity. Visual search performance in Experiment 1 was better for learned than for unlearned transsaccadic associations, although a post-saccadic blank of 200 ms made transsaccadic object changes during learning of false associations highly visible. By contrast, no advantage in visual search performance could be revealed for previously learned transsaccadic associations if spatial instead of temporal object continuity was disrupted. A task-irrelevant shape change from circle to triangle successfully impaired transsaccadic learning in Experiment 2. Thus, our results indicate that in transsaccadic learning continuity of spatial object properties is more relevant than continuity of temporal object properties.

56.430 **The roles of cuing and visual working memory capacity in dynamic oculomotor selection** Matthew Weaver[1](Matthew.Weaver@unitn.it), Davide Paoletti[1], Wieske van Zoest[1]; [1]CIMeC, University of Trento, Italy

It is accepted that goal-directed strategies can use advanced information about the properties of a search display to directly influence covert attentional selection. However, relatively little work has investigated this benefit on overt saccadic selection. The aim of the present study was to: 1) explore how the impact of advanced knowledge provided by a cue develops over time to influence oculomotor selection; and 2) examine the role played by individual differences, as reflected by visual working memory capacity (VWMc), in utilizing this cue to benefit selection performance. Participants responded to a particular line orientation target in a visual search task. Additionally, the target or an irrelevant distractor could be unique in color – creating a color singleton – or they were equally salient. Prior to each trial, color singleton identity (target, distractor, or neither) was either validly cued or not cued at all. Saccadic responses were separated into time bins to assess the timecourse of cue impact on selection accuracy. A change-detection task provided a measure of VWMc. The cue influenced dynamic oculomotor selection in three specific ways: 1) it increased accuracy performance from the earliest saccadic responses; 2) this benefit increased with later saccadic responses to target-color singletons; 3) this increasing benefit was sufficient to only reduce, and not eliminate, an overall decrease in accuracy performance over response latency. Individuals' VWMc scores were associated with cue impact, whereby participants with higher capacity derived an increased performance benefit from the cue. These findings suggest that strategic use of cue information to select and reject salient singletons can develop very early following display presentation and is related to an individual's VWMc. This research indicates that stimulus-driven and goal-directed processes are not simply additive in oculomotor selection, but instead exhibit a distinct and dynamic profile of interaction.

56.431 **Can eye movements anticipate the laterality of an unpredictable stimulus?** Simon Thorpe[1](simon.thorpe@cerco.ups-tlse.fr), Magaly Alonzo[1], Jacob Martin[1]; [1]Centre de Recherche Cerveau & Cognition, CNRS-Université Toulouse 3, Toulouse, France

It was recently claimed that humans can perform above chance at guessing where on a screen an image will appear, even when the location is determined by a hardware random number generator (RNG) after the subject has made their response (Bem, 2011, J Pers Soc Psychol, 100, 407). If true, such results would have serious implications for out own work on ultra-rapid visual processing. Studies using a saccadic choice task have shown that eye-movements towards face targets can be initiated just 100 ms after stimulus onset (Crouzet et al, 2010, J Vis) and face localization can be determined from around 50 ms on the basis of ERP recordings (Martin et al, VSS, 2014). Here, we specifically investigated whether fast eye movements might involve anomalous anticipatory responses of the type reported by Bem. After a variable delay, a central fixation cross was replaced by two crosses located on the left and right, and subjects had to saccade to one of them. Once the saccade was underway, a hardware

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RNG selected left or right at random. If the saccade direction matched the direction selected by the RNG, a well-known and surprising image was presented beyond the location of the target cross, coupled with a lateralized matching audio stimulus (e.g. “Bugs Bunny” coupled with “What’s up Doc?”). If the saccade direction differed from the one selected by the computer, no image or sound was presented. Clearly, subjects should not normally be able to perform above chance on such a task and reliable performance over 50% would imply some sort of anomalous anticipation of unpredictable events. Initial results suggest that at least some subjects may be able to perform at above chance, but conclusive results will require extensive additional testing with large numbers of subjects.

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56.432 **How does visual search behaviour adapt when partners have a response bias?** Charlotte A Riggs[1](c.a.riggs@soton.ac.uk), Hayward J Godwin[1], Tamaryn Menneer[1], Simon P Liversedge[1], Nick Donnelly[1]; [1]Psychology, University of Southampton

Some real-world tasks involve observers visually searching in pairs or teams (e.g. searching buildings for weapons). One issue that has not yet been explored is how search behaviour adapts or shifts when a partner in a pair shows signs of missing targets or making false alarms. In the present study, we examined participants’ eye movements and behavioural performance (accuracy and reaction time) in a visual search task where two targets could appear. The participants were instructed that they must search for one target, and were informed that a partner had already searched the same displays for a second target. The participants were told that they could also search for the partner’s target if they so wished. Following each trial, they were given feedback relating to both their own performance and their partner’s performance. The key manipulation that we implemented was relating to the partner’s performance since the partner did not, in fact, exist. Partner responses were determined according to a pre-defined signal-detection theory criterion. One group of participants were teamed with a conservative-criterion partner (where the partner had a bias to respond ‘absent’), while a second group were teamed with a liberal-criterion partner (where the partner had a bias to respond ‘present’). While overall accuracy was equivalent across conservative-criterion and liberal-criterion conditions, reaction times for those paired with a conservative-criterion partner were slower than for those paired with a liberal-criterion partner. Longer reaction times for this group were driven by more fixations and increased verification times (time between first fixating the target and responding ‘present’). These results demonstrate that direct experience of conservative search behaviour in a partner influences an observers search speed but not accuracy. We suggest that working with a partner who is likely to miss targets fosters a conservative approach to responding in visual search tasks.

56.433 **When caused by an eye movement inhibition of return’s effect is post-perceptual: Evidence from SAT functions** Ralph S. Redden[1](rredden@dal.ca), Matthew D. Hilchey[1], Raymond M. Klein[1]; [1]Dalhousie University

Inhibition of return (IOR) is an inhibitory aftermath of orienting typically seen in the form of slower response to targets presented in the previously attended location. IOR has been shown to exist in two mutually exclusive forms (Taylor & Klein, 2000): an effect on motoric processes (an output form) is observed when the oculomotor system is not suppressed and an effect on attentional/perceptual processes (an input form) when the oculomotor system is suppressed. Whereas Chica, Taylor, Lupianez, and Klein (2010) discovered that when caused by an eye movement to an uninformative peripheral cue, the delay in responding to targets at the originally cued location (the IOR effect) was accompanied by more accurate responding (a speed-accuracy tradeoff). It is impossible to tell from their data pattern if this evidence for a criterion shift was or was not accompanied by a genuine improvement in information processing. We investigated the trading relation between speed and accuracy when IOR was caused by an eye movement to a spatially-uninformative cue by implementing five 210 ms response windows (beginning 120ms, 240ms, 360ms, 480ms, and 600ms after the target’s appearance) within which observers were required to make a non-spatial discrimination about the target. By generating speed-accuracy tradeoff functions as proposed by Wickelgren (1977) and implemented by Ivanoff and Klein (2006), we determined the output form of IOR is characterized exclusively by a criterion shift, as represented by performance at both cued and uncued locations existing on a single speed-accuracy function.

Eye movements: Perception and neural mechanisms

Tuesday, May 20, 2:45 - 6:45 pm
Poster Session, Banyan Breezeway

56.434 **Effects of spatial frequency filtering in natural scenes: Evidence from eye movements and computational modeling** Anke Cajar[1](cajar@uni-potsdam.de), Jochen Laubrock[1], Ralf Engbert[2]; [1]Cognitive Sciences, University of Potsdam, [2]Experimental and Biological Psychology, University of Potsdam

When looking at a scene, the foveal and peripheral visual field serve different functions. The fovea is most sensitive to high spatial frequencies and ideally suited for object identification and the analysis of details, while the peripheral field is sensitive to low spatial frequencies for saccade target selection and processing transients. How do spatial frequencies affect eye movements during scene viewing? We investigated this question in several experiments by selectively attenuating parts of the spatial frequency spectrum in the foveal or peripheral visual field. This was achieved by applying gaze-contingent high-pass or low-pass filters to natural scenes either in the foveal or the peripheral field of the viewer, thus simulating a foveal scotoma or tunnel vision. Compared to an unfiltered control condition, fixation durations increased with filter conditions where processing was predicted to be easier (foveal high-pass and peripheral low-pass filtering), while fixation durations were less affected when processing was predicted to be more difficult (foveal low-pass and peripheral high-pass filtering). These counterintuitive results challenge current theories of eye-movement control, which expect a positive correlation of fixation durations and (foveal) processing difficulty. We therefore implemented a computational model with two spatial compartments where foveal and peripheral processing interact to control fixation durations. The model reproduced experimental distributions and mean values of fixation durations by varying few parameters that were affected by the specific filtering conditions. The modeling results suggest that (1) peripheral information is critical for the control of fixation durations, and (2) foveal and peripheral information processing evolve in parallel and interact.

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56.435 **Characteristics of ambient and focal processing during the visual exploration of dynamic stimuli** Sebastian Pannasch[1](sebastian.pannasch@tu-dresden.de); [1]Engineering Psychology and Applied Cognitive Research, Department of Psychology, Technische Universitaet Dresden, Germany

Analyzing the time course of eye movements during free exploration of real-world scenes often reveal an increase in fixation durations together with a decrease in saccade amplitudes which has been explained as a shift from ambient (global) to focal (local) processing. The ambient mode refers to bottom-up processing, serving global orientation controlled by the saliency of the stimulus. In contrast, the focal mode is rather related to top-down processing and associated with the identification of object features. The ambient-to-focal strategy seems to be evoked by the onset of images but a systematic investigation for dynamic stimuli is still missing. If this pattern represents an omnipresent viewing characteristic for new visual information, it should also be evoked by the onset of dynamic scenes. Furthermore, an interruption of the dynamic information flow, caused by a scene change, might also lead to a restart of the ambient-to-focal strategy. To address this question, we recorded videos where the viewer walked through indoor scenarios when no other persons were present. From the recorded material we generated 3 different video clips, each with an approximate length of 10 minutes, containing several scene changes. Scene changes were defined as either abrupt scene cuts (e.g. cut from room to staircase) or pan shots (horizontal camera scans providing a new perspective). We analyzed fixation durations and saccade amplitudes focusing on the time course of visual exploration following the video onset, differences before and after scene changes, and spatio-temporal characteristics of the viewing behavior in relation to the stimulus saliency and the scanning similarity between subjects. Initial results indicate the ambient-to-focal strategy also for the exploration of dynamic stimuli. These findings further support the ambient/focal distinction, which can help to decode complex viewing pattern into distinct processing levels that are related to the interplay of bottom-up and top-down mechanisms.

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56.436 **Pupil size is larger when viewing indoor scenes** Chencan Qian[1,2](qianchencan@gmail.com), Zuxiang Liu[1]; [1]Institute of Biophysics, Chinese Academy of Sciences, [2]University of Chinese Academy of Sciences

It is long known that pupil size is modulated by luminance of stimuli, and arousal or cognitive effort of subjects. Recently, several groups suggested that higher-level perceptual interpretation also impacts pupil size, e.g., perceived brightness and lightness (Laeng & Endestad, 2012; Naber & Nakayama, 2013). Here we investigated pupillary responses when subjects were viewing scenes from three different top-level categories: indoor, man-made (outdoor), and natural. In Experiment 1, 10 subjects were showed 210 distinct grayscale images (70 from each category) automatically drawn from a large database, intermixed with their phase scrambled version. All images were preprocessed to have identical mean pixel value of 0.5. The subjects engaged in a visual search task for a local spatial distortion randomly embedded in the image, while binocular eye movement and pupil size were continuously recorded at 1000 Hz with EyeLink 1000. In Experiment 2, vertically inverted, as well as polarity (black-white) inverted versions of the original images were shown instead, to another group of participants. After initial contraction following stimulus onset, the pupil dilated as the subject kept on searching. Interestingly, pupil size was significantly larger for “indoor” scenes than “man-made”, which in turn larger than “natural”. Physical luminance, contrast, and task difficulty failed to explain the results, since “indoor” was actually associated with slightly higher mean luminance and contrast (luminance variance), and was less difficult (shorter response time and higher percentage correct) than “natural”, which predicted the opposite results. Notably, the difference between “indoor” and “man-made” diminished in scrambled, vertically inverted, and polarity inverted conditions, although “natural” still resulted in smaller pupil size than other categories. We suggest that pupil size was larger when subjects were viewing indoor compared with outdoor scenes, partly because the latter might be subjectively perceived as brighter, a learnt regularity from everyday experiences.

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56.437 **Gaze Bias in Perception for Canine and Human Faces** Bruce Bridgeman[1](bruceb@ucsc.edu), Cory Little[1]; [1]Department of Psychology, University of California, Santa Cruz

The ability to read emotional information from a face has clear evolutionary advantages for social animals. Recent research shows that humans have a gaze bias towards the left side of a face image (the right side of the face), and this bias might be controlled by the emotional content of the face. This might be due to more emotional expression on the right side of the face. Since canines have been co-evolving with humans for thousands of years, we might process canine faces in a similar manner. We investigated lateral gaze bias to photographs of objects, human faces, and dog faces. If gaze bias is based on a fixed preference to inspect the right side of the face more then the left, left-right reversal of the face should not have an effect. We found that reversing the image did not change the scanpath for either dogs or human faces, but there was a significant bias to look more on the left side of the image for dog faces than human faces. This suggests that when a face is thought to express more emotion, there is more left bias for the image, not specifically the right side of the original face. We found no support for the alternative hypothesis that the decision about where to concentrate the gaze is determined in real time by immediately available cues. Rather, the right-face bias is hard-wired.

56.438 **The influence of crowding on eye movements: A preliminary study** Senay Aydin[1](senay.aydin@anglia.ac.uk), Mofiyinfoluwa Adeleye[1], John Siderov[1], Akash S. Chima[1], Harold E. Bedell[2], Sarah J. Waugh[1], Josselin Gautier[1]; [1]Anglia Vision Research, Department of Vision and Hearing Sciences, Anglia Ruskin University, Cambridge, United Kingdom., [2]University of Houston, College of Optometry, Houston, USA.

It is well known that nearby contours impair visual discrimination, a phenomenon, which is defined as crowding. We used letter targets with different surrounding features to investigate the influence of foveal crowding on fixation. Six participants, aged between 20-36 years, monocularly fixated on 6 different high-contrast targets presented at 0.1 logMAR above resolution threshold: a single letter H; a letter H surrounded by 4 flanking bars at either 1 or 2 stroke widths; a letter H surrounded by 4 flanking letters at either 1 or 2 stroke widths; and a line of 7 identical letter Hs. Participants sat 4m from the target display with head movements restrained by a forehead rest and bite-bar. The participants were instructed to keep their gaze directed at the center of the stimulus as stably as possible throughout each 15s trial. Each trial was shown 8 times and stimuli were presented in a random order.The horizontal and vertical position of the viewing eye was recorded using an Eyelink II at a sampling frequency of 250 Hz. The results indicate that fixation stability, expressed as log bivariate contour ellipse area, was generally poorer for the line of letters than when fixating on a single letter target. Fixation stability assessed using differently crowded letter targets appears relatively unaffected by surrounding crowding features except when the fixation letter is located in a line of similar targets. This result is consistent with the notion that observers can sometimes lose their place in a line acuity task.

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56.439 **Caucasian and Asian eye movement patterns in face recognition: A computational exploration using hidden Markov models** Tim Chuk[1](saltwort@gmail.com), A. Xiao Luo[1], Kate Crookes[2], William G. Hayward[1], Antoni B. Chan[3], Janet Hsiao[1]; [1]Department of Psychology, The University of Hong Kong, [2]ARC Centre of Excellence in Cognition and Its Disorders, School of Psychology, University of Western Australia, [3]Department of Computer Science, City University of Hong Kong

In our recent face recognition study (Chuk et al., 2013), we recruited Asian participants and used a hidden Markov model (HMM) to represent each individual’s eye movement patterns. The HMM estimates regions of interests (ROIs) on the face, and the probability of transitions between ROIs. We then clustered the individuals’ HMMs into two groups using a data-driven algorithm, and discovered that one group exhibited holistic eye movement patterns while the other exhibited analytic patterns. However, previous studies (Kelly et al., 2011) considered these two eye movement patterns to be markers of Asians and Caucasians, respectively. Here we recruited 24 Caucasian and 24 Asian participants to study 28 faces and then recognize them among 56 faces; eye movements were recorded. We trained one HMM per individual using all fixations, and then clustered the HMMs into two groups. We discovered that more Asians (19) than Caucasians (14) were in the analytic group. However, when the HMMs were clustered into three groups, we discovered that some Asians used a different analytic pattern that mainly shuffled between the face center and the right eye. The two races differed in their group distributions ($\chi2(2) = 8.064$, $p = .018$). Since past studies suggested that the first few fixations suffice for face recognition (Hsiao & Cottrell, 2008), we also trained the individuals’ HMMs using the first three fixations in each trial. Similar to the all fixation case, our clustering algorithm found two analytic and one holistic groups, but the difference in group distribution between the two races were non-significant ($\chi2(2) = 2.411$, $p = .300$). In conclusion, our data-driven analyses discovered a previously unknown eye movement pattern among Asians and that cultural difference emerges after the first few fixations. These findings were not possible using previous methods that do not consider individual differences and transition information.

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56.440 **A Visual Field Asymmetry in Pre-saccadic Fixation Durations** Harold Greene[1](greenehh@udmercy.edu), James Brown[2], Barry Dauphin[1]; [1]Psychology department, University of Detroit Mercy, [2]Psychology department, University of Georgia

Many pro-saccadic reaction time studies have revealed a shorter latency to initiate saccades towards the upper visual field than the lower visual field. Our concern was temporal processing during free-scanning eye movements. For free-scanning visual exploration, the temporal metric includes not only saccade reaction time, but also the time used for perceptual processing of information at the fixated location. If asymmetries are reliably present in free-scanning exploration of scenes, this must be considered in computational modelling of human fixation durations. Eye movements were monitored as observers engaged in three different free-scanning visual exploration tasks (i.e., 2 types of visual search tasks, and a Rorschach ambiguous image-interpretation task). Pre-saccadic fixation durations (PSFDs) associated with saccades directed within the visual field were compared for 80 naïve participants (at least 12 per task). For each task, PSFDs were placed in 10-deg direction bins, and analyzed using a 36-level, one-way ANOVA. The analyses indicated that PSFDs were not equally long in different directions (all ps <.01). For post hoc probing, we divided the 360-deg visual field into four 90- deg sections. Orthogonal contrast analyses revealed a vertical field asymmetry for each task, such that PSFDs were shorter by about 50 ms for saccades directed upwards than downwards (all ps <.01). We speculate that the vertical asymmetry observed for PSFDs was more likely related to saccade programing constraints, than to the human experience of biasing visual attention towards extra-personal space in the upper-visual-field. Whatever the correct explanation, the ability to predict PSFDs is important for computational modelling of real-time exploration of visual scenes. The findings make a case for also including directional constraints in computational modelling of when the eyes move.

56.441 Saccade planning evokes topographically specific activity in the dorsal and ventral streams Clayton Curtis[1](clayton.curtis@nyu.edu), Golbarg Saber[1], Franco Pestilli[2]; [1]New York University, [2]Stanford University

Persistent neural activity in frontal cortex may reflect spatially specific feedback signals that bias activity in early visual cortex in favor of top-down goals. Here, we tested one key aspect of this hypothesis by measuring cortical activity in human retinotopic areas along the dorsal and ventral visual processing streams while subjects maintained over long memory delays planned saccades to or away from visual targets. In general, our results support the hypothesis that activity persists in the specific parts of the retinotopic maps that represent the location of the saccade goal. Topographically specific activity persisted as early as V1 and persisted not only in dorsal but in ventral visual areas. Moreover, activity persisted during the memory delay when the visual target was only available via working memory, and therefore reflects top-down mechanisms. Finally, when the visual target and saccade goal were spatially disassociated, delay activity was enhanced at the retinotopic locations representing both the visual target and the saccade goal. We conclude that the effects of spatially specific top-down signals elicit corresponding activity in early retinotopic visual areas and along the dorsal and ventral visual streams. Such a gain enhancement might underlie the mechanisms that prioritize the locations of task relevant items in visual space.

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56.442 An image-based population model of human saccade programming in the Superior Colliculus Hossein Adeli[1](hossein.adelijelodar@stonybrook.edu), Soazig Casteau[2], Françoise Vitu[2], Gregory Zelinsky[1,3]; [1]Department of Psychology, Stony Brook University, USA, [2]Laboratoire de Psychologie Cognitive, Aix-Marseille Université, France, [3]Department of Computer Science, Stony Brook University, USA

Models of saccade programming in the superior colliculus (SC) have been limited in what inputs they can accept, typically isolated coordinates in visual space (e.g., Ottes et al., 1986, Vision Research [1]). We addressed this problem by integrating [1] with an image-based model of visual search (Zelinsky, 2008, Psychological Review). This new model inputs an image, which it correlates with target features to create a map of target evidence in visual space. Using equations from [1] it then projects this distribution of visual activity onto a map of the collicular surface, where each neuron's activity is a Gaussian-weighted sum of its inputs. We then compute across the SC a Gaussian-weighted average of the population activity within an averaging window. The location of the maximum averaged activation determines the landing position of the saccade in visual space following the inverse transformation from [1]. We tested this model against human behavioral data from a saccade-targeting task (Casteau & Vitu, 2009, ECEM15; 2011, ECEM16 [2]) where the separation between the target and a less-eccentric distractor, displayed at variable eccentricities, was systematically varied. These data showed that the likelihood of saccades landing at intermediate target/distractor locations decreased as inter-stimulus distance increased, and that this averaging distance increased with eccentricity in visual space but remained relatively constant when expressed in collicular space. By varying the sigma of our model's averaging window, we were able to fit the data from [2], reproducing their evidence for saccade averaging at small target/distractor separations, a breakdown of averaging at large target/distractor separations (saccades directed to one or the other item), and an interaction between inter-stimulus distance and item eccentricity. This demonstrates the efficacy of our model, but its main contribution lies in the fact that predictions of saccade programming, and the collicular activation underlying this programming, can now be made for arbitrarily-complex objects and scenes.

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56.443 Steady-state sensory-evoked responses are enhanced prior to oculomotor execution Kimberly E Kaye[1](kimberlyevekaye@gmail.com), Thomas C Sprague[2], Sirawaj Itthipuripat[2], Elena C Prado[1], John T Serences[1, 2]; [1]Department of Psychology, University of California, San Diego, [2]Neurosciences Graduate Program, University of California, San Diego

Experiments evaluating the relationship between sensory and oculomotor systems have utilized a variety of methods to evaluate the extent to which these systems are interrelated, how they interact, and the mechanisms that influence them. Results from psychophysics, microstimulation, and electrophysiology all suggest an enhancement of sensory processing when the oculomotor system is activated – that is, prior to the onset of a saccade, visual discrimination performance is improved at the saccade endpoint (Rolfs & Carrasco, 2012), and electrophysiological responses measured from individual neurons (Moore et al, 1998) and the scalp (Krebs et al, 2012) are enhanced. However, disentangling population-level signals related to top-down control/motor preparation and those purely related to sensory processing is often challenging. To address this issue, we measured steady-state visual evoked potentials (SSVEP) using electroencephalography (EEG) prior to the onset of voluntary saccades towards flickering stimuli in the left and right visual fields. On each trial, observers were presented with an endogenous cue at fixation, instructing them to saccade towards a corresponding flickering checkerboard stimulus or maintain fixation. We observed an increase in SSVEP power evoked by the saccade target just prior to saccade onset compared to SSVEPs during fixation trials in which the eyes did not move. This work reinforces the utility of the SSVEP technique in isolating sensory responses during an oculomotor task, and suggests that sensory-driven signals can be enhanced prior to oculomotor execution.

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56.444 Comparative connectivity of frontal eye field and striatum between humans and macaques Michelle Young[1](michelle.s.young@vanderbilt.edu), Bas Neggers[2], Bram Zandbelt[1], Jeffrey Schall[1]; [1]Department of Psychology, Vanderbilt Vision Research Center, Center for Integrative and Cognitive Neuroscience, Vanderbilt University, Nashville, Tennessee 37240, United States, [2]Brain Center Rudolf Magnus, Dept. of Psychiatry, University Medical Centre Utrecht, the Netherlands

Classically, the cortico-basal ganglia circuits has been described in terms of segregated ocular motor and skeletal motor loops. The ocular motor loop begins with projections from the frontal eye fields (FEF) to the caudate nucleus, and the skeletal motor loop begins with projections from the motor cortex (M1) to the putamen. This description has been guided by anatomical and physiological findings in macaques. Recent neuroimaging studies of the human FEF reveal inconsistencies with this organization. Using probabilistic diffusion tractography, we compared the in-vivo pattern of connectivity between humans and macaques. Nine healthy humans were scanned at the UMC Utrecht. Nine healthy adult macaques were scanned at Vanderbilt University Institute of Imaging Science. All subjects were imaged in the same type of scanner (Phillips Achieva 3T) with similar pulse sequences and analysis pipelines. We found that the FEF cortico-strial pathways differed between macaques and humans. In macaques the FEF is connected with the head of the caudate and dorsomedial putamen, in agreement with neuroanatomical tract tracer findings. However, in humans FEF is connected to posterior putamen and a small portion of the caudate body. The differences in connectivity may be explained by the evolutionary expansion of prefrontal projections to striatum in humans.

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56.445 Direction specific signals for saccadic eye movements: Effects of traumatic brain injury Christopher Tyler[1](cwt@ski.org), Lora Likova[1], Spero Nicholas[1]; [1]Smith-Kettlewell Eye Research Institute

Introduction. Although the frontal eye field (FEF) regions of monkey cortex exhibit direction-specific coding contralateral to saccade direction, the same differentiation is not found with fMRI measures in humans. There is weak (~20%) direction specificity for memory-guided saccades and for the direction of attention, but none has been reported for visually-guided saccades. Methods. We have introduced a stepwise (ziggurat) paradigm of 10 leftward saccades followed by 10 rightward saccades to provide sufficient periods of unidirectional saccades in a block-design protocol on a 3T Siemens scanner. The study was conducted in a group of individuals with a history of diffuse traumatic brain injury (with loss of consciousness but no focal brain damage, dTBI) and a group of age-matched controls. Results. Outside occipital cortex (where direction specificity is expected due to the directional visual stimulation), A restricted locus of bihemispheric direction specificity was seen in the region of the precen-

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tral gyrus (Brodmann 4) often designated as the human homolog of the FEF, together with the saccadic region of the superior parietal lobule (SPL). The dTBI group showed significantly reduced signals in the FEF, but undiminished direction-specific activation in in the occipital cortex regions and in the SPL (providing assurance that the reductions were specific to the motor activation regions). Conclusion. The main centers for direction-specific saccadic activation were in focal FEF, SPL and occipital cortex. These activations may be interpreted as reflecting, respectively, the initiation of directional control signals, the spatial representation of the direction target and the visual consequences of the eye movements. The direction-specific region of FEF was the main cortical area adversely affected by dTBI.

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56.446 **Deviation in saccade trajectories suggests asymmetric representation of the upper and lower visual fields in the superior colliculus** Zhiguo Wang[1](z.wang@hznu.edu.cn); [1]Center for Cognition and Brain Disorders, Hangzhou Normal University, China

Previous studies have shown that saccades may deviate towards or away from task irrelevant visual distractors (Van der Stigchel, Meeter, & Theeuwes, 2006). The deviation away from distractors is stronger for targets in the lower visual field (LVF) than those in the upper visual field (UVF). Using a distractor task, three experiments were conducted to elucidate the mechanism underlying this observation. Extending previous findings, stronger deviation away from distractors was observed for LVF targets, regardless of being presented on (Exp. 1) or 15° off (Exp. 2) the vertical meridian, for a large range of target-distractor distance (15°-165°). One possible explanation is that, compared to the UVF, the LVF is under-represented on oculomotor maps, such as the superior colliculus (SC). To test this hypothesis, in Experiment 3, the distractor (if presented) was put at a location that mirrored the target in the opposite visual field (upper or lower). Thus, for a given target-distractor distance (30°, 60°, 90°, 120° or 150°), the directional deviation in collicular space was comparable for targets in the UVF and LVF. Canonical mathematical model of the SC (van Gisbergen, van Opstal, & Tax, 1987) assumes symmetric representations of the UVF and LVF in the SC and thus predicts equivalent directional deviation for targets in the UVF and LVF in Experiment 3. However, stronger directional deviation was observed for targets in the LVF. Because the target-distractor distance in collicular space was the same for targets appeared in the UVF and LVF, the findings of Experiment 3 provide unambiguous behavioral evidence for the hypothesis that the LVF is under-represented in the SC.

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Eye movements: Perisaccadic perception

Tuesday, May 20, 2:45 - 6:45 pm
Poster Session, Banyan Breezeway

56.447 **Spatiotopic visual representations and oculomotor plasticity** Thérèse Collins[1](collins.th@gmail.com); [1]Laboratoire Psychologie de la Perception, Université Paris Descartes & CNRS

Each saccadic eye movement modifies the retinal coordinates of visual objects. Despite the constant changes in retinal inputs, we perceive the visual world as stable. Visual stability is probed in the laboratory by asking participants to perform saccades to targets that are displaced during movement execution and measuring their perception of those displacements. Correct performance depends on an accurate spatiotopic representation of object positions and thus can be used as an index of spatiotopic processing. Displacing targets during the execution of the movement also leads to oculomotor plasticity: artificial undershoots caused by stepping the target forwards tend to be followed by larger-amplitude saccades, while artificial undershoots caused by stepping the target backwards tend to be followed by smaller-amplitude saccades. Performance on the spatiotopic task is inversely related to oculomotor plasticity: the better participants are at aligning pre- to post-saccadic retinal coordinates on a spatiotopic map, the less their saccade amplitudes change from trial to trial. However, variations of performance in the spatiotopic task were not always mirrored by variations in oculomotor plasticity. For example, performance on the spatiotopic task can be enhanced by inserting a temporal blank between saccade offset and displaced target appearance, but results suggest that the blank does not interfere with plasticity, suggesting that constructing spatiotopic representations across eye movements and oculomotor plasticity depend on only partially overlapping processes.

56.448 **The infinite regression illusion reveals dissociation between perception and action** Matteo Lisi[1](matteo.lisi@parisdescartes.fr), Patrick Cavanagh[1,2]; [1]Laboratoire Psychologie de la Perception (CNRS UMR 8158), Universitè Paris Descartes, Paris, France, [2]Department of Psychology, Harvard University, Cambridge, MA, USA

Many psychophysical studies showed that visual motion can influence the perceived location of stationary stimuli. A classical result is that a stationary aperture filled with a drifting grating appear to be displaced in the direction of motion (De Valois & De Valois, 1991). This illusion also affects the visuomotor system as saccades to static, drifting Gabor patches show landing positions shifted in the direction of motion (Kosovicheva, Wolfe, & Whitney, 2012; Schafer & Moore, 2007). In the present study we presented stimuli that combined motion within the aperture (internal motion) and motion of the aperture itself (external motion), with the direction of one motion vector orthogonal to the other, as in the infinite regress illusion of Tse and Hsieh (2006). This combination leads to a striking illusion where the perceived direction of the aperture is given by a nonlinear sum of the two motion vectors (Tse & Hsieh, 2006). We find that when the external motion is along a path tilted ~35° from the vertical, the orthogonal internal motion can make the path appear vertical. This creates a large offset between the perceived and the physical location of the aperture, up to twice the size of the aperture itself (8 times the sigma of the Gaussian envelope) at the two endpoints of the motion path. We measured both the perceptual and saccadic localization of brief flashes superimposed on the motion stimuli. Surprisingly, we found that saccades did not show the perceptual position shifts, but instead targeted the physical locations of the flashes. Overall, the data highlight a dramatic dissociation between action and perception and suggest that, unlike perception, the saccade system is able to isolate the external target motion and ignore the irrelevant internal motion.

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56.449 **Trans-saccadic integration of spatial frequency information in an fMRIa paradigm.** B.-R. Baltaretu[1,2,4](brb@yorku.ca), B. T. Dunkley[1,3], J. D. Crawford[1,2,4,5]; [1]Centre for Vision Research, York University, Toronto, Ontario, Canada, [2]Canadian Action and Perception Network (CAPnet), [3]Department of Diagnostic Imaging, Hospital for Sick Children, Toronto, Ontario, Canada, [4]Department of Biology, and Neuroscience Graduate Diploma Program, York University, Toronto, Ontario, Canada, [5]Departments of Psychology, Biology, and Kinesiology and Health Sciences, and Neuroscience Graduate Diploma Program, York University, Toronto, Ontario, Canada

To date, there is no direct evidence showing where and how visual features are stored and integrated across saccades in the human brain. Recently, using an fMRI 'adaptation' paradigm we found two cortical regions that showed greater sensitivity to same vs. different stimulus orientations that were more robust with intervening saccades than fixation: one in the right inferior parietal lobule (supramarginal gyrus; SMG) and one in right extrastriate cortex, likely V4 (Dunkley and Crawford, Society for Neuroscience Abstracts 2012). Here, we used a similar paradigm to test if these trans-saccadic interactions are feature-specific. Eleven participants viewed a vertical grating of a given spatial frequency in the center of the screen whilst fixating to the left or right of the stimulus. Subsequently, a second stimulus was presented with the same spatial frequency (Repeated condition) or with a different spatial frequency (Novel condition). In the intervening period, participants were required to either fixate in the same position (Fixation task) or to make a saccade to the opposite fixation point (Saccade task). Participants were required to indicate if the stimulus changed or stayed the same. The Saccade task data produced significant ($p < 0.05$) adaptation (novel > repeated frequency) in both left and right parietal cortex around SMG, consistent with our results from the previous spatial orientation study. However, we found no significant adaptation or summation effect around V4 (consistent with its known greater sensitivity to orientation vs. frequency). Results from the Fixation task showed significant adaptation in left inferior parietal cortex. Taken together with our previous experiment, this demonstrates that inferior parietal cortex is involved in trans-saccadic integration of both spatial orientation and frequency, whereas V4 is involved in field- and feature-specific integration for orientation. This suggests dual feature-specific and feature-independent mechanisms for trans-saccadic integration of objects in human cortex.

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56.450 **Visual and spatial determinants of saccadic suppression of displacement** Heiner Deubel[1](heiner.deubel@psy.lmu.de), David Aagten-Murphy[2], Bruce Bridgeman[3]; [1]Dept of Psychology, Ludwig-Maximilians-Universität München, Germany, [2]Dept of Psychology, Ludwig-Maximilians-Universität München, Germany, [3]Dept of Psychology, University of California, Santa Cruz, USA

The displacement of a stimulus is often not perceived when it occurs during a saccade. This "saccadic suppression of image displacement" (SSID) is considered to be an important factor for the maintenance of visual stability across eye movements, because it bridges potential errors in stimulus remapping resulting from inaccuracy of extraretinal information. SSID however also depends on visual and spatial properties of the stimulus. It has been reported for horizontal saccades that intrasaccadic target steps are easier to detect if they occur orthogonal to the direction of the saccade, and that a brief postsaccadic blanking of the target leads to a marked improvement of displacement detection. To investigate the components that affect perceived constancy, we measured SSID for a wide range of saccade directions and different intrasaccadic target step directions. Results showed that intrasaccadic steps orthogonal to saccade direction were indeed more easily detected than collinear steps for saccades in all directions, with this difference being largest for horizontal and vertical saccades. A signal detection analysis showed these effects to be differences in sensitivity, not bias. Sensitivity was unrelated to the magnitude of postsaccadic fixation error showing that trial-to-trial oculomotor error did not contribute to post-saccadic localization. Moreover, when oblique saccades were analyzed, sensitivity to displacement was unrelated to saccade endpoint variability, which contrasts with previous reports. In a second set of experiments the target was blanked for 200ms after the saccade, leading to an increase of sensitivity for displacements by a factor of about 1.4 for all saccade directions.

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56.451 **Unmasking saccadic masking: an objective measure to constrain the possible mechanisms of saccadic masking** Marianne Duyck[1](Marianne.Duyck@parisdescartes.fr), Thérèse Collins[1], Mark Wexler[1]; [1]Laboratoire Psychologie de la Perception, CNRS & Université Paris Descartes, Paris, France

One hypothesis accounting for the fact that we are not aware of the retinal smear caused by saccades in normal viewing situations is that this smear is masked by pre and/or post-saccadic static images (Matin, Clymer & Matin, Science 1972; Campbell & Wurtz, Vis. Res. 1978). We establish an objective measure of saccadic masking by presenting a point light source during the saccade, which--if not masked--was perceived as a smear. A brief luminance decrease of the point light source at various times during the saccade resulted in the percept of a hole in various locations in the smear. Without pre- or post-saccadic masks, subjects could reliably report the location of the hole. We varied the presence and duration of forward (pre-saccadic) and backward (post-saccadic) masks by additionally illuminating the point light source before and after the saccade. We found a decrease in hole localization performance with increasing mask durations, as measured by the slope of single-stimuli psychometric functions. Interestingly, we also found significant individual differences in susceptibility to masks in general, and in differential susceptibility to forward versus backward masks. To examine the origin of saccadic masking, we correlated performance in the saccadic smear masking task with performance in classic visual masking tasks during fixation. We hypothesize that if masking of saccadic smear is a purely visual process, individual differences in susceptibility to masking should generalize across the two different masking paradigms.

56.452 **Feature remapping precedes saccadic eye movements without attention** Dongjun He[1](hedongjunspc@pku.edu.cn), Fang Fang[1,2,3]; [1]Department of Psychology and Key Laboratory of Machine Perception (Ministry of Education), Peking University, [2]Peking-Tsinghua Center for Life Sciences, Peking University, [3]IDG/McGovern Institute for Brain Research, Peking University

Saccadic eye movements, which typically occur two to three times every second, dramatically change the images on the retina; however, conscious perception is stable and continuous. One possible explanation for visual stability is the predictive remapping mechanism. Although previous works have found evidence for predictive remapping of attention pointers and attended features, no study has examined the existence of the predictive remapping of unattended features before a saccade. This would be helpful to discriminate two remapping mechanisms: activation transfer (attention is necessary) and shifting receptive fields (attention is not necessary). In this study, we used the psychophysical adaptation technique to measure aftereffects, including the tilt aftereffect (TAE), the motion aftereffect (MAE) and the threshold elevation aftereffect (TEAE) at the remapped location of an adapting stimulus before a saccade. Subjects first adapted to a peripherally presented stimulus. After a saccadic cue, subjects needed to execute an eye movement to a saccadic target and perform a visual task at the remapped location of the adaptor for measuring the aftereffects just before the saccade. Because the adaptor disappeared before the occurrence of the saccadic cue, there was no attention to the adapted feature immediately before and during the saccade. We found a significant TAE and MAE at the remapped location, but no TEAE. These findings imply that extrastriate areas (but not the striate area) could remap visual features, even without attention. Furthermore, we found that the TAE magnitude increased with the interval between the onset of the saccadic target and the onset of the saccadic cue. This finding suggests that the aftereffect at the remapped location develop slowly before the saccade. Taken together, our results provide further psychophysical evidence for the shifting receptive field mechanism of remapping.

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56.453 **Probing the dynamics of perisaccadic perception with EEG** Lyudmyla Kovalenko[1,3](lyudmyla.kovalenko@hu-berlin.de), Niko Busch[2,1]; [1]Berlin School of Mind and Brain, Humboldt-Universität zu Berlin, [2]Charité University Medicine, [3]Department of Psychology, Humboldt-Universität zu Berlin

Perceptual stability is a phenomenon that defines our subjective visual experience: as we navigate through the environment, the visual image appears spatially and temporally continuous. In reality, however, it is fragmented into separate fixational images that are displaced with each saccade. How are these discrete retinal snapshots connected to create a continuous percept? Two physiological processes that have been shown to shape perisaccadic perception are pre-saccadic shift of attention and saccadic suppression. While the attentional shift enhances visual sensitivity, saccadic suppression inhibits it to minimize retinal blur. Both processes are transient and active already before saccade onset. In our study, we probed the dynamic interplay of these two effects using electroencephalography (EEG) co-registered with eye tracking. Participants fixated on a central cross until cued to make a rightward or leftward saccade to target. At 220 ms after cue onset, a probe stimulus (checkerboard) was flashed for 30 ms in the left or right hemifield. All subsequent analyses were restricted to trials on which the saccade followed probe presentation. For these trials, we computed the lateralization patterns of probe-evoked EEG potentials, i.e. amplitude differences between electrodes contralateral vs. ipsilateral to the probe. Lateralization was compared between trials on which probe and saccade target appeared in the same or in different hemifields. In the early pre-saccadic period (100-140 ms after probe onset), we found stronger lateralization for probes that appeared in the same hemifield as the saccade target, indicating an effect of a perisaccadic attention shift. In the later pre-saccadic period (after 140 ms), we observed a transient reduction in lateralization independent of probe position that we attribute to perisaccadic suppression.

56.454 **rTMS Over Human Early Visual Cortex Degrades Low Level Visual Feature Memory in the Remapped, Not Perceived, Visual Field During a Transsaccadic Integration Task** Pankhuri Malik[1,2,6](pankhuri@yorku.ca), Joost Dessing[2,3], Douglas Crawford[1,4,5,6]; [1]Department of Biology, York University, 4700 Keele Street, Toronto, Ontario, Canada, [2]Centre for Vision Research, York University, 4700 Keele Street, Toronto, Ontario, Canada, [3]School of Psychology, Queen's University, University Road, Belfast, Northern Ireland, UK, [4]Departments of Psychology and Kinesiology and Health Sciences, York University, 4700 Keele Street, Toronto, Ontario, Canada, [5]National Coordinator, Canadian Action and Perception Network (CAPnet), [6]Neuroscience Graduate Diploma Program, York University, 4700 Keele Street, Toronto, Ontario, Canada

Early visual cortex (EVC) is involved in short term visual memory (Harrison and Tong Nat Neurosci. 2009) and remapping of visual targets during saccades (Merriam et al. J. Neurophys. 2007). We proposed that EVC is also involved in transsaccadic integration (TSI) of visual features (Prime et al. Exp Brain Res 2006; J. Neurosci. 2008). Here, we tested this hypothesis with the use of a combined fMRI-rTMS protocol. Participants (n = 8) were required to discriminate orientation change in a Gabor patch across a memory interval during fixation or across saccade that either maintained the stimulus within the same visual field (VF) or changed location to opposite VF. Difficulty levels were set to 75-85% performance for each subject based on a preliminary test. Bifield alternating checkerboard localizer was used to identify peak voxel responses within the left and right EVC corresponding to bottom-left and bottom-right VF. rTMS (10Hz; starting 100 msec after onset of second fixation point) was applied over either of these two locations during the fixation task and saccade task, and effects were compared

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to behavioral controls and relative to TMS over the opposite VF. Consistent with previous experiments with one object (van de Ven et al. J. Neurosci. 2012), TMS during the fixation task (and for saccades within the same field) had no rTMS effects. rTMS over EVC corresponding to the viewed location of the initial stimulus never yielded an effect in any condition. However, when the saccade caused the remembered stimulus to reverse VF, TMS over the 'incoming' field (i.e. the EVC target site for any putative remapping) revealed a suppressive effect, which increased with saccade size (and/or the eccentricity of remapping into the stimulated hemifield). These results causally implicate human EVC (and/or its network connections) in the gaze centered remapping TSI visual feature information across saccades.

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56.455 **Perceptual Consequences of Delaying the Post-saccadic Target** Brent Parsons[1](brent.parsons@berkeley.edu), Richard Ivry[2]; [1]Vision Science Graduate Group, University of California, Berkeley, [2]Department of Psychology, University of California, Berkeley

Studies of saccadic adaptation have predominately focused on manipulations in the spatial dimension. Shifting the location of the saccade target midflight leads to changes in the motor command (e.g. saccade amplitude) and affects subsequent perceptual judgments (e.g. localization). Significant gain reduction has been reported even when the shifted target is presented at post-saccade delays of up to 400ms (Shafer, Noto, & Fuchs 2000). Recent experiments manipulating only the temporal dimension, the delay between saccade landing and target presentation, have shown changes in peak velocity of the saccade (Shadmehr et al. 2010). The current study investigates the perceptual consequences of this delayed sensory input. Subjects were asked to judge the duration of a stimulus presented at different delays after saccade landing. The closer in time to the completion of the eye movement the longer the percieved duration of the target stimulus. Our results seem at odds with a previous explanation of temporal distortions around saccades (Yarrow, Haggard, & Rothwell 2010) and are in line with a more general account of how humans adapt to delayed sensory input following voluntary action (Parsons, Novich, & Eagleman 2013).

56.456 **Remapped and Captured Pre-Saccadic Attention Produces Perceptual Facilitation at Non-target Locations** Michael Puntiroli[1](Michael.Puntiroli@unige.ch), Dirk Kerzel[1], Sabine Born[1,2]; [1]Psychologie et des Sciences de l'Education, Université de Genève, [2]Laboratoire Psychologie de la Perception, Université Paris Descartes

An important question in the field of visual attention is how attentional resources are distributed over space and objects prior to saccades. Literature agrees that saccades are tightly linked to attention. Even when saccades are erroneously directed at a distractor location, there is evidence that this location is visited by pre-saccadic covert attention (Peterson, Kramer & Irwin, 2004). However, the conclusion was based on a counter-intuitive negative compatibility effect in reaction times. Our goal was to better understand the allocation of attention in an oculomotor capture paradigm for straight-to-target saccades and for capture saccades that are followed by corrective saccades to the target. In contrast to classic oculomotor capture studies, we measured the deployment of attention not through reaction time differences, but through perceptual discrimination performance. A dual-task was employed requiring saccades towards a shape singleton target, in the presence of a color singleton distractor. The secondary task was to discriminate an asymmetric cross presented in one of six possible locations (including target and distractor locations). We found perceptual facilitation effects at the target location for straight-to-target saccades, and at the distractor location when oculomotor capture occurred. Thus, in contrast to Peterson et al. (2004), we observed a positive effect of attention at the distractor location. Interestingly, facilitation effects at the target location decreased when the eye had been captured by the distractor. This was especially true when the eyes dwelled long on the distractor before the corrective saccade to the target was launched. Furthermore, we found increased perceptual discrimination at a non-target location during capture trials, which, in line with recent findings by Rolfs et al. (2011), coincided with the remapped location of the saccade target. Results are discussed in terms of temporal and spatial facilitation, parallel programming of saccades and the cross-saccadic maintenance of attention on target objects.

56.457 **Sensitivity to spatiotopic location in the human visual system** Yuval Porat[1](yporat@gmail.com), Tanya Orlov[1], Ayelet Mckyton[1], Ehud Zohary[1,2,3]; [1]Neurobiology Department, Life Sciences Institute, Hebrew University of Jerusalem, Jerusalem 91904, Israel, [2]Interdisciplinary Center for Neural Computation, Hebrew University of Jerusalem, Jerusalem 91904, Israel, [3]The Edmond & Lily Safra Center for Brain Sciences, Hebrew University of Jerusalem, Jerusalem 91904, Israel

Introduction: Visual information in the early visual processing stages is represented in strictly eye□centered (retinotopic) coordinates. Thus, each eye movement, generating a different retinal image, evokes a different pattern of activity, although the visual scene is unaltered. Our perception, however, shows clear visual stability. This may indicate that non□retinotopic representations (i.e. head, body or world-; termed 'spatiotopic') are invoked higher in the visual pathways. It is, however, unclear where in the brain and under what conditions such representations emerge. Methods: Subjects (N=13) participated in a block□designed fMRI repetition suppression (RS) experiment. In each block, a series of identical or different objects appeared. Eye movements were made between stimulus presentations, such that objects were either in the same screen position (e.g spatiotopic) or in different positions (non-spatiopic). Spatiotopic and non-spatiotopic blocks were equated in terms of their distribution of retinal positions of the stimuli. Results: 2x2 ANOVA performed on the activation parameters revealed 3 different effects: regions along the LOS, OTG, ITG, and fusiform gyrus were sensitive to the identity of the object (i.e. an Identity RS). In contrast, parietal regions (aIPS, pIPS, and SPL) were differentially activated when stimuli appeared in the same spatiotopic position (spatiotopic-position RS). Finally, some regions (pFus, LOS and occipito-parietal junction) revealed an interaction effect: the identity RS was greater when objects appeared in the same spatiotopic location. Conclusion: Our results suggest that the spatiotopic location of objects (irrespective of their identity) is encoded in parietal cortex. Currently, it is unclear, if the spatiotopic-position RS was mainly due to the repetition at the same position, or prior knowledge of object position, as objects repeatedly appeared in the same screen location throughout the block. An ongoing event-related task design may elucidate the contribution of these factors to the emergence of spatiotopic representations in the visual system.

56.458 **The role of visual stability on the representation of saccade target object** Caglar Tas[1](caglar-tas@uiowa.edu), Cathleen Moore[1], Andrew Hollingworth[1]; [1]Department of Psychology, University of Iowa

Perceiving a stable world across saccades requires integration of pre- and post-saccadic information. We have previously proposed that transsaccadic integration depends on an object-mediated updating process (Tas et al., 2012). Specifically, if stability is achieved, and the post-saccadic target object is perceived as the continuation of the pre-saccadic object, the remembered properties of the pre-saccadic object are overwritten by the post-saccadic properties. However, if stability is not achieved (e.g., due to discontinuity in spatial or surface features across the saccade), pre-saccadic features are protected from being overwritten by the post-saccadic features, because the pre- and post-saccadic objects are mapped to different object representations. The present study provided a direct test of this object-mediated updating account. Participants executed a saccade to a colored target object. On some trials, visual stability was disrupted by blanking the target for 250 ms after saccade initiation, so that no object was visible for a brief period after the eyes landed (Deubel et al., 1996). To test the precision of the pre-saccadic object representation, on some trials the color of the saccade target was changed to a different color during the saccade. The magnitude of this color change was adjusted so that it did not disrupt visual stability. At the end of each trial, participants reported either the pre- or post-saccadic color using a continuous recall procedure, in which participants selected the appropriate color from a color wheel. Consistent with the object-mediated updating account, pre-saccadic color was preserved and could be reported with high precision when visual stability was disrupted (blank trials). However, when stability was achieved (no-blank trials), memory for the pre-saccadic color was significantly impaired, indicating that the process of integrating color representations into a single, persisting object representation leads to substantial overwriting of the initial properties of the object by subsequently perceived properties.

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56.459 **Similar effects of saccades on auditory and visual localization suggest common spatial map** Hannah Krüger[1](hannah.krueger@gmail.com), Therese Collins[1], Patrick Cavanagh[1]; [1]Centre Attention and Vision, Laboratoire Psychologie de la Perception, Université Paris Descartes, Paris, France & CNRS UMR 8158, Paris, France

The perception of space across different sensory modalities is one of a seamless whole, despite the fact that the inputs to these modalities are processed in their own specific reference frames (e.g. retinotopic, tonotopic or somatopic). Visual orienting has been shown to influence localizing of sources of other modalities [Pavani, Hussain & Driver, 2008; Pritchett, Carnevale & Harris, 2012]. Here we ask the question whether localizing auditory stimuli is influenced by saccades in a similar manner as localizing visual stimuli. The direction of apparent motion across eye movements is systematically misperceived to occur further in direction to the eye movement [Szinte & Cavanagh, 2011]. This effect has been related to the structure of an attention map that dynamically updates visual space across eye movements based on predictions about where visual stimuli appear on the retina after a saccadic displacement. We asked subjects to indicate the tilt of an apparent vertical, auditory motion for four degrees of tilt (extreme left, medium left, medium right, extreme right). Participants had no bias in judging this tilt when instructed to maintain fixation at a peripheral location. When asked to judge the tilt across eye movements, the orientation of subjective vertical was rotated in direction of the intervening eye movement. This finding is in line with the illusory perception of a tilt of transsaccadic visual apparent motion [Szinte & Cavanagh, 2011] and as such supports the notion that orienting to and localizing of auditory sources is updated across eye movements similar to that seen for visual stimuli. As such the presented results point towards a common mechanism for the perception of space across modalities.

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56.460 **The intention to make a saccade distorts the timing of a Go/No-go signal presented at fixation** Yoshiko Yabe[1,2](yyabe@uwo.ca), Melvyn Goodale[1]; [1]The Brain and Mind Institute and the Department of Psychology, University of Western Ontario, [2]Research Institute, Kochi University of Technology

Research has shown that the intention to perform an action can distort one's perception of the timing of sensory events that occur after the action is initiated (Haggard et al., 2002; Kawabe et al., 2013). Here we show that, when participants are required to initiate a saccade, a distortion occurs in the perception of the timing of the 'go signal'. The saccadic trigger is perceived to have occurred later than it really did. This illusion also occurred on no-go trials in which the participant was instructed to maintain fixation. Participants viewed a black dot displayed on a computer screen. A hand rotated around the dot like a conventional clock. In a Go/No-go task, participants were asked to make a rapid eye movement towards a target that was presented 16° to the right of fixation if the 'clock' turned green and to not make a movement if the clock turned red. In the control condition, the participants saw the same changes in the colour of the clock presented at fixation while attending to the black target, but were never required to move their eyes. In both tasks, the participants were required to report, at the end of each trial, the location of the clock hand at the moment the clock changed colour. The ratio of the frequency of green vs. red trials was 7:3. The perceived position of the clock hand in the control task was not significantly different from the real timing of the colour change. In the go/no-go condition, there was a significant increase in the perceived timing of the colour change – even when participants did not move their eyes. This result suggests that the temporal distortion of the saccadic trigger is caused by the intention to make a saccade, not by the saccade itself.

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Binocular Vision: Rivalry, competition and suppression

Tuesday, May 20, 2:45 - 6:45 pm
Poster Session, Pavilion

56.501 **Deficits in feature counting in amblyopes under binocular viewing** Xin Jie Lai[1](angela@ski.org), Chuan Hou[1]; [1]Smith-Kettlewell Eye Research Institute

In strabismic amblyopes, the amblyopic eye markedly underestimates the number of features in a brief presentation (Sharma et al., 2000), and the ability to direct attention quickly to targets of interest is impaired. We speculated that under binocular viewing, the performance of feature counting might be further reduced in strabismic amblyopic observers due to the delay in the deployment of attention. To test this idea, we measured feature counting in normal and amblyopic observers, using vertical Gabor stimuli (2cpd, 0.7-degree, 200-msec duration) presented at random locations within the central visual field. In the test condition, Gabors were presented to the left or right eye at random on each trial, preceded (500-msec) by a 5.6-degree square frame that cued which eye received the stimuli. In the control condition, Gabors were presented only to the left or to the right eye. Observers viewed the stimuli in a stereoscope and were asked to report the number of stimuli (0 to 9). The contrast of the Gabors was balanced between the two eyes. We also measured the performance under the test condition with distractors (horizontal Gabors) simultaneously presented to the non-tested eye at non-corresponding retinal locations. In normal observers, performance was unaffected by switching the cue between eyes (test condition). Consistent with previous work, we found reduced performance only in the amblyopic eye in the control condition. However, in the test condition, amblyopic observers dramatically underestimated the number of Gabors in both eyes. In normal observers and amblyopes with residual binocularity, performance was reduced in both eyes when distractors were presented to the non-tested eye. However, this reduction was not found in stereo-blind amblyopes. Our results indicated that in stereo-blind amblyopes, the added burden of monitoring both eyes simultaneously reduced performance on feature counting, and this reduction was not due to interocular suppression.

56.502 **Binocular rivalry using luminance- and contrast-modulated stimuli** Jan Skerswetat[1](Jan.Skerswetat@anglia.ac.uk), Monika A. Formankiewicz[1], Sarah J. Waugh[1]; [1]Anglia Vision Research, Department of Vision and Hearing Sciences, Anglia Ruskin University, Cambridge, U.K.

Binocular rivalry is competition that occurs when incompatible stimuli are presented to the two eyes. The percept changes over time and originates either exclusively from one eye or is a mixture of the two stimuli. The mixed percepts are thought to represent periods of partial binocular integration (Klink et al., 2010). The processing of contrast-modulated stimuli is thought to occur in higher and more binocular areas of visual cortex, than that of luminance-modulated stimuli (Wong et al., 2005). We investigated whether these proposed differences in processing loci are reflected in the characteristics of binocular rivalry. Binocular rivalry was investigated for luminance (L), luminance-modulated (LM) and contrast-modulated (CM) stimuli with sizes of 1, 2 and 4 deg and spatial frequencies of 4, 2 and 1 c/deg, respectively. Orthogonal sinusoidal gratings were presented dichoptically to the two eyes. Six participants with normal vision completed 72 trials, each lasting at least 120 seconds, in counterbalanced order. The task was to indicate whether the left, right or mixed stimulus was perceived. Visual exclusivity, i.e., the proportion of time when only the right or left grating was visible, was significantly greater for LM (52±5%) and L (51±5%) than CM (14±4%) stimuli ($p<0.05$) and decreased with increasing stimulus size (50±6%, 41±6% and 26±6% for 1, 2 and 4 degrees, respectively). The average duration for the mixed CM percept was longer (~60 sec) than the mixed LM (~5 sec) and mixed L (~4 sec) one, and than the exclusive percepts for all types of stimuli (~1, ~2, ~1 sec for L, LM and CM, respectively). The low level of visual exclusivity and long periods of mixed perception or 'partial binocular integration' for CM stimuli provide further evidence for the involvement of more binocular visual areas in the processing of CM than L/LM stimuli.

Acknowledgement: Faculty of Science and Technology Research Studentship, Anglia Ruskin University, UK

56.503 **The Role of Monocular Dominance in Rivalry Onset Bias** Jody Stanley[1](jodys@unimelb.edu.au), Jason Forte[1], Alexander Maier[2], Olivia Carter[1]; [1]Melbourne School of Psychological Science, University of Melbourne, [2]Department of Psychology, College of Arts and Sciences, Vanderbilt University

When an observer is presented with dissimilar images to the right and left eye, the images will alternate every few seconds in a phenomenon known as binocular rivalry. Recent research has suggested that at the initial 'onset' period of rivalry there is typically a bias towards one image, which varies between individuals and across the visual field, and does not appear to be related to average dominance in sustained viewing. To further characterize the role that monocular dominance plays in the onset bias, 4 trained observers were presented with a small 0.75 degree patch of orthogonal achromatic gratings at the fovea and at 24 locations, sampling the region within 1.5 degrees eccentricity from the fovea. Gratings were presented for 1 second with 20 trials in each location. Gratings were also presented twice in every location for 1 minute to compare any onset bias with average dominance over sustained viewing. Results reveal individual differences in the contribution of eye dominance to the onset bias, with

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individuals displaying degrees of either right eye dominance or temporal hemifield dominance. When compared with sustained viewing, 3 out of 4 observers showed correlations between onset biases and biases in average dominance. These results demonstrate that monocular dominance plays a significant role in determining dominance at the onset of rivalry, though there are individual differences in the pattern of bias across the visual field. Monocular dominance can also affect dominance in ongoing rivalry in a way that correlates with the onset bias; however, this does not seem to be the case for all observers, suggesting that the neural mechanisms underlying onset and sustained rivalry may be distinct. In addition, some initial data assessing the relationship between onset bias and the stabilization seen with intermittent presentation will also be discussed.

56.504 **The effects of inter-ocular contrast differences on binocular rivalry in younger and older observers** Amanda M. Beers[1](beersam@mcmaster.ca), Allison B. Sekuler[1], Patrick J. Bennett[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University

Beers et al. (VSS 2013) demonstrated that monocular dominance (MD) during binocular rivalry increases significantly with aging. Age differences in optical factors, such as sensitivity to inter-ocular contrast differences could provide an explanation. To investigate potential age-related changes in MD, we measured binocular rivalry in younger (aged 20-28) and older (aged 70-79) adults using pairs of orthogonal, oblique sine wave gratings that differed in contrast. In baseline conditions, rivalry was measured with equal stimulus contrasts (0.2 or 0.8) presented to both eyes. In the test condition, stimulus contrast was 0.2 in one eye and 0.8 in the other eye, with the eye viewing the higher contrast counter-balanced across trials. During each trial, participants reported their perceptual state by pressing buttons on a response box (the two exclusive percepts, mixed, and fading). MD was defined as the difference between the proportion of time a participant reported seeing each exclusive percept. MD in the baseline conditions was significantly greater in older than younger adults, supporting our previous findings. However, MD did not differ between age groups in the test condition. The introduction of an inter-ocular contrast difference of 0.6 caused MD to increase significantly in younger adults, whereas the contrast difference had an insignificant effect in older adults who already had shown strong MD in baseline conditions. A follow-up experiment measured binocular rivalry in younger adults with a wider range of inter-ocular contrast differences: 0, 0.2, 0.4, and 0.6. A contrast difference of 0.4 was needed to produce a level of MD that was approximately equivalent to that found in older adults with contrast-matched stimuli. These results demonstrate that a large difference in inter-ocular contrast is required to produce MD in younger adults that is equivalent to the MD found in older adults, suggesting neural changes in binocular vision with aging.

Acknowledgement: Canadian Institutes of Health Research (CIHR), Canada Research Chairs Program, and Vanier Canada Graduate Scholarship Program

56.505 **Invisible Chromatic Gratings Can Induce Orientation-Specific Adaptation and Binocular Rivalry** Jinyou Zou[1](jjzou_6@163.com), Sheng He[1,2], Peng Zhang[1]; [1]State Key Lab of Brain and Cognitive Science, Institute of Biophysics, Chinese Academy of Sciences, [2]Department of Psychology, University of Minnesota

Binocular rivalry arises when incompatible patterns of stimuli were dichoptically presented. Previously, we found that spatial attention is necessary for dichoptic images to be engaged in sustained rivalry (Zhang et al, 2011). The current study examined whether binocular rivalry can be induced from stimuli with invisible spatial patterns. Counterphase flickering red/green chromatic gratings were adopted as stimuli. At 30Hz flickering frequency, the red/green gratings were perceived as stable uniform yellow. In experiment 1, following adaptation to an invisible chromatic grating, observers perceived a significant tilt after effect and also had an orientation-specific detection threshold elevation. In experiment 2, with one eye presented with a low contrast static red/green grating, the fellow eye was presented with, all perceptually matched, either a invisible flickering red/green grating, flickering uniform red/green patches, or a static uniform yellow patch. Observers reported their perceptual experience using button presses: the low contrast grating, part of the grating, or uniform yellow. Result showed that the total duration for seeing the uniform yellow was slightly but significantly longer when the stimulus in the fellow eye was an invisible grating, compared to the other two control conditions without spatial pattern. Together these results show that the chromatic grating rendered invisible due to fast flicker can induce orientation-specific adaptation as well as enhance interocular competition.

56.506 **Neural signature of the initiation of binocular rivalry** Sucharit Katyal[1](skatyal@umn.edu), Shinho Cho[2], Stephen Engel[3], Sheng He[4]; [1]Department of Psychology, University of Minnesota Twin Cities

When differing visual inputs reach the two eyes, the visual system in some cases integrates them into a fused percept, while in others produces rivalry, with only one perceived at a time. The process by which the visual system determines whether two images should be fused or should rival remains relatively unstudied. We investigated this process using SSVEP. It is known that when rivaling dichoptic stimuli are modulated at two different frequencies, f1 and f2, the SSVEP amplitudes reflect the rivalry alternations. Here we measure SSVEP with stimuli that were only slightly different between the two eyes to look for the presence of a neural signature that reflects a state in between fusion and rivalry. Two orthogonal square-wave gratings (±45°, f1=4.72 Hz, f2=8.5 Hz) were dichoptically presented to three subjects on an 85 Hz monitor. In one condition all gratings had contrast of 0.5, leading to binocular fusion. In three other conditions, the contrast of the 45° grating in one eye and the –45° grating in the other eye were reduced by 0.1, 0.2, or 0.4, which changed the percept from complete fusion to clear rivalry. Each condition was presented in three 50-sec blocks while SSVEP was recorded using a 64-channel EEG. For all four conditions significant SSVEP amplitudes were obtained over occipital electrodes at the fundamental frequencies f1and f2. For the 0.1% contrast-reduction condition there was a significant SSVEP amplitude at the beat frequency (f2– f1), which was greater than all other conditions. Perceptual reports showed that rivalry was completely absent in this condition. The enhanced beat frequency response is an identifiable neural signature for the state where the stimulation between the two eyes is non-identical, but rivalry has not yet begun. We speculate that this might be relevant to the neural processes responsible for the initiation of rivalry.

Acknowledgement: R01EY023101

56.507 **When our brain is convinced: EEG correlates of visual ambiguity** Jürgen Kornmeier[1](juergen.kornmeier@uni-freiburg.de), Rike Wörner[2], Michael Bach[3]; [1]Institute for Frontier Areas of Psychology and Mental Health, Freiburg, Germany, [2]PPD Germany GmbH & Co Kg Karlsruhe, Germany, [3]Eye Center, Albert-Ludwigs-University of Freiburg, Germany

During the observation of an ambiguous figure, like the Necker cube, our perceptual system is unstable and alternates spontaneously between two (or more) mutual exclusive representations. Tiny figural changes can disambiguate the ambiguous figure, thus stabilize one representation and induce two sizable ERP components, a fronto-central P200 and a parieto-central P400. These ERPs are absent with ambiguous stimulus variants. This pattern of results was found with geometric (Necker lattice) and semantic (Old/Young woman) stimuli. In the current study we looked (1) for similar effects with ambiguous and unambiguous motion stimuli and (2) for correlations between the degree of ambiguity and the amplitude of the two ERP components. Methods: 12 Participants (six females) viewed ambiguous SAM (stroboscopic alternative motion) and Necker lattice stimuli and variants with different degrees of disambiguation in separate experimental blocks. Stimuli were presented discontinuously (≈ 800 ms) with short blank-screen intervals (≈ 20 ms) and participants manually indicated perceptual alternations between presentations. EEG traces were sorted for stimulus category (geometry, motion) and degree of ambiguity and averaged to ERPs. Latencies and amplitudes of P200 and P400 were analyzed. Results: (1) Tiny figural changes, rendering an ambiguous figure unambiguous, evoke two sizable positivities at about 200 and 400 ms after stimulus onset ("P200/P400 Ambiguity Effect"), which are absent with the ambiguous figures. (2) The two ERP amplitudes increases linearly with decreasing ambiguity of the stimulus. (3) This P200/P400 Ambiguity Effect was replicated for the Necker lattices and also found with SAM motion stimuli. Our results suggest the existence of a neural evaluation instance that estimates the reliability of the perceptual outcome, given limited and ambiguous visual input. This evaluation seems to work on a processing level generalized across sensory domains.

56.508 **Afterimage duration reflects how deeply invisible stimuli were suppressed** Motomi Shimizu[1](shimizumtm@chiba-u.jp), Eiji Kimura[2]; [1]Graduate School of Humanities and Social Sciences, Chiba University, Japan , [2]Dept of Psychology, Faculty of Letters, Chiba University, Japan

[Background] A monocularly-presented high-contrast dynamic pattern such as a counterphase-flickering grating can produce strong interocular suppression and render invisible another stimulus presented to the other eye, even when the stimulus is of high contrast. Under these situations, psychophysical quantification of the interocular suppression is difficult because the stimulus cannot be seen. This study demonstrates that the

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duration of afterimage of the invisible stimulus can be used to quantify the strength of suppression. [Methods] The suppressing stimulus was a counterphase-flickering Gabor patch (1.5 cpd, s=0.22, ~100% contrast). Flickering frequency was 5 Hz. During exclusive dominance of the suppressing stimulus, a static Gabor patch (adaptor, with the same spatial properties and contrast) was presented to the other eye for 3 sec. After the offset of the two stimuli, observers indicated afterimage duration by holding down a button as long as the afterimage was visible. The relative orientation of the adaptor to the suppressing stimulus was varied from 0 to 90°. Only the trials were used to measure afterimage duration on which observers did not see the adaptor at all throughout the adaptation period. [Results & Discussion] Even when the adaptor was completely suppressed from awareness, afterimage duration varied as a function of the relative orientation. The duration was almost zero when the relative orientation was 0°, and increased gradually with relative orientation. Interestingly, when the relative orientation was 90°, the duration was nearly the same as that under the no-suppression condition where the adaptor was clearly visible throughout the adaptation period. Clearly, afterimage duration did not depend on adaptor visibility, but reflected the strength of interocular suppression which exhibited orientation selectivity. These findings suggest that afterimage formation at least partly involves an early cortical process and that afterimage duration can be a useful psychophysical measure of strong interocular suppression.

56.509 **The effect of contextual depth on binocular rivalry** Chun Siong Soon[1,2](chunsiong.soon@duke-nus.edu.sg), Mei Ying Ng[1], Po-Jang Hsieh[1]; [1]Brain and Consciousness Lab, Duke-NUS Graduate Medical School , [2]Department of Psychology, Technical University Dresden

The fusion of interocularly paired stimuli with offsets in position can yield depth information with high precision. Similarly, the interocularly unpaired points of a partially occluded object – seen in one eye but not the other – also provides important binocular depth cues (Nakayama and Shimojo, 1990). A stereo mechanism estimates the relative depth relations between objects using such unpaired points. It has been proposed that when interocularly unpaired points do not satisfy natural occlusion geometry, stable depth assignment fails, resulting in binocular rivalry (Hayashi et al., 2004). If binocular rivalry is indeed the erroneous output of occlusion relation estimation, then one might expect that the relative depths of rivaling stimuli could affect their visibility. Here we hypothesize that perceptual dominance of a stimulus during binocular rivalry is associated with that stimulus having a shallower depth. We tested this hypothesis by measuring whether a relatively shallower stimulus would be more dominant than a deeper ("occluded") stimulus in two experiments. A convex or concave contextual depth was first established by manipulating the positional disparity of two annuli. Rivaling stimuli (Experiment 1: red vs green patches; Experiment 2: left- vs right-tilted Gabor patches) were then presented for 500ms, 1000ms, or 1500ms between the two annuli, at the same distance from fixation. 6 subjects reported that the shallow stimulus was more frequently dominant for both color and Gabor patches in the convex context at 1000ms and 1500ms. No differences were found in the concave depth context. Our results provide partial support for the hypothesis that contextual depth can affect stimulus dominance during rivalry.

56.510 **Special role of parietal cortex in binocular rivalry demonstrated by fMRI comparison with stimulus rivalry** Janine Mendola[1](janine.mendola@mcgill.ca), Athena Buckthought[1], Jeremy Fesi[1]; [1]McGill Vision Research, Dept. Ophthalmology, McGill University

Binocular rivalry results in perceptual alternations with conflicting images in each eye. Stimulus rivalry allows a similar percept despite repeated swapping of the images in each eye (Logothetis et al, 1996, Blake, 2001). Recent studies have further characterized the parameters required for rivalry, and proposed an integrated framework that may suggest a similar mechanism for both types of rivalry (Van Boxtel et al, 2008). However, a direct comparison of binocular and stimulus rivalry with fMRI has not been reported. We tested subjects with matched stimuli in both rivalry conditions. The stimuli were 1.4 cpd sinusoidal gratings (left & right oblique orientations) at 3.8 deg. Luminance contrast was 100%. For binocular rivalry, dynamic images were presented dichoptically (with polarizers) for 90msec periods with a periodic short blank ISI of 60 msec. For stimulus rivalry, the stimuli were identical except that the images shown to each eye were swapped at 6.67 Hz. We employed active scans where subjects indicated alternations with key press, as well as scans with passive viewing only. Overall, cortical activation for binocular rivalry was consistently greater than for stimulus rivalry. In whole brain statistical maps, this was pronounced in the intraparietal sulcus. Follow-up analysis with retinotopic regions of interest showed also that binocular rivalry exceeded stimulus rivalry in V1, V2, V3, and V3A. Based on comparisons between active and passive conditions, we interpret parietal activity to reflect a relatively automatic process that is triggered by object individuation/attentional tracking. In contrast, regions of ventral temporal cortex might reflect active categorization demands. These results suggest that despite a global network similar to binocular rivalry, the increased interocular masking in stimulus rivalry results in lower BOLD signals as early as V1, consistent with a lower effective contrast and slower alternations. These physiological observations are relevant to competing models of rivalry.

Acknowledgement: NSERC Discovery Grant

56.511 **Global brain networks contrasted by stability of Binocular Rivalry** Masanori Shimono[1](nori417@gmail.com), Kazuhisa Kazuhisa[2]; [1]Indiana University, USA, [2]AIST, Japan

This presentation shows how the global organization of brain networks relates with stability of perceptions alternating by Binocular Rivalry phenomenon (Shimono, Niki, 2013, Brain Connectivity). Binocular Rivalry has been always played the central role which is key to understanding neuronal processes of conscious and unconscious visual experiences for many decades (Blake, Logothetis, 2001; Tong, Meng, Blake, 2006). Recently, the Connectomic-approach is prominently contributing in developments of neuroscience especially in understanding function-structure relationships in human brains (Sporns, Tononi, Kotter, 2005; Van Essen, Ugurbil, 2012). Currently, how the global organization of brain networks relates with our various cognitive behaviors is becoming an important question to be asked. This study firstly connects between these two important streams to understanding interactions among brain regions dealing with the processing of visual information. First, we reconstructed global brain networks connecting between 84 segmented brain regions by tracking fibers of white matter recorded as Diffusion Tensor Images (DTIs). Second, we compared between the inter-individual difference of stability of perceptual alternations in Binocular Rivalry and inter-individual differences of variables calculated from DTIs, which is interpreted to relate with "information efficiency" of the reconstructed fiber tracts. As a prominent finding, the high "efficiency" of subcortico-subcortical networks widely related with the stabilization of the perceptions, and the high "efficiency" of cortico-cortical networks widely related with the un-stabilization of the perceptions. Many recent neuroscientific studies of Binocular Rivalry have deliniated important various brain regions. The finding in this study will additionally provide us an important basis to understand how global interactions as networks among the various brain regions are creating the optimal environment for visual information processes. Reference: Shimono, Masanori, and Kazuhisa Niki. "Global Mapping of the Whole-Brain Network Underlining Binocular Rivalry." Brain connectivity 3.2 (2013): 212-221. http://online.liebertpub.com/doi/pdfplus/10.1089/brain.2012.0129

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56.512 **Statistical learning facilitates the identification of targets in perceptual competition with learned images** Rachel Denison[1](rdenison@berkeley.edu), Jacob Sheynin[2], Michael Silver[1,3]; [1]Helen Wills Neuroscience Institute, University of California, Berkeley, [2]College of Letters and Science, University of California, Berkeley, [3]School of Optometry and Vision Science Graduate Group, University of California, Berkeley

Visual statistical learning allows the rapid acquisition of sequential regularities in the visual environment. However, the implications of this type of learning for subsequent visual perception are not well understood. We have recently shown that statistical learning of natural image sequences influences perceptual selection during binocular rivalry by increasing the likelihood of perceiving an unexpected image over an expected, learned image (VSS 2012). Here, we asked whether this tendency for statistical learning to enhance perception of the unexpected image improves performance on an objective target identification task. Subjects viewed a stream of three-item image sequences (triplets). The sequences of images in the triplets were consistent throughout the experiment in order to allow statistical learning of the triplets to take place over the course of the experimental session. The image stream was presented dichoptically, and on some image presentations, target face images were embedded within the stream by presenting them to one eye, while the other eye was presented with the appropriate next image in the stream. Therefore, target images and learned images were engaged in binocular rivalry. Subjects' task was to identify faces as male or female whenever they saw them. Comparing the first half to the second half of the experiment, we found improvements in target accuracy (percent correct) and discrimination (percent correct normalized by percent detected) that were specific to targets paired with the third image in the triplets. These results are consistent with the idea that learning the image sequence regularities selectively improved perception of targets that rivaled with the most strongly predicted images, compared to targets that rivaled with images less strongly predicted by the learned sequence. These results raise the possibility that one function of visual statistical learning may be to enhance perception of unexpected items relative to those that can be anticipated.

56.513 **Comparing the influences of emotion versus identity on face perception during binocular rivalry in human observers**

Nour Malek[1](nour.malek@mail.mcgill.ca), Andy Gao[1], Daniel Messinger[2], Karim Tabbane[3], Ridha Joober[3], Julio Martinez-Trujillo[1]; [1]Cognitive Neurophysiology Laboratory, Department of Physiology, McGill University, Montreal, QC, CA, [2]Departments of Psychology, Pediatrics, and Electrical and Computer Engineering, University of Miami, Coral Gables, FL, USA, [3]Douglas Hospital Research Centre, Montreal, QC, CA

Binocular rivalry (BR) is the conscious alternation between two images that are presented to each eye. BR experiments using face stimuli have focused on the influence of emotions by often presenting 2D black and white photos or simplistic, unnatural cartoons of faces; findings from such studies have primarily determined that positive facial expressions dominate (i.e., are perceived longer) over negative ones. While the significance of emotion during rivalry has been meticulously studied, the global significance of the entire face (i.e., identity) carrying the emotion has scarcely been touched upon. To determine whether identity also influences BR face perception, or whether emotion is the paramount factor affecting a face stimulus' dominance, six 3D, realistic faces, with varying skin tone, gender, and facial features, expressing one of three emotions (happy, neutral, or sad) were created using a random face generator software (FaceGen Modeller). Different identities expressing identical emotions, identical identities expressing identical emotions, and identical identities expressing different emotions were all rivaled against one another, as five human subjects reported which stimulus (comprising of both emotion and identity) were perceived throughout the stimuli's presentation. As anticipated, positive expressions were found to dominate over negative ones when expressed by the same identity ($p<1.24x10-22$, Kolmogorov-Smirnov [KS]). Also, when comparing the dominance durations of rivaling different identities expressing the same emotion, identity was found not to have a significant effect on alternation rates ($p>0.6019$,KS). Interestingly, however, the strong dominance effect of positive expressions became disputable upon setting different identities to rival. Comparisons of dominance durations for each emotion when rivaled with identical identities versus with different identities exhibited significant differences ($p<0.0358$,KS), indicating an effect of identity on the percept of emotions. Overall, while emotion appears to play a much greater role in the percept of faces than identity, a significant interaction exists between the two.

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56.514 **Unconscious Syntactic Processing in the Absence of Semantics**

Shao-Min Hung[1](konaes@gmail.com), Po-Jang Hsieh [1]; [1]Neuroscience and Behavioral Disorders Program, Duke-NUS Graduate Medical School Singapore

Syntactic processing is long regarded autonomous. However, whether people can process syntax unconsciously even in the absence of semantics is still unknown. In the current study, we tested the possibility of unconscious syntactic processing by presenting syntactically congruent and incongruent sentences and measured whether they could be processed differently even without awareness due to visual suppression. Syntactically congruent sentences follow the Subject-Verb-Object format while syntactically incongruent sentences follow the Subject-Verb-Verb (Experiment 1a) or Subject-Verb-Adjective (Experiment 2a) format. In each trial, the first two words were presented consciously while the third word being suppressed with continuous flash suppression. Our results showed that syntactically incongruent words broke suppression significantly faster than syntactically congruent words. Furthermore, the same effect was obtained with sentences composed of pseudo-words that contained no semantics at all. These findings indicate that both consciousness and semantics are not necessary for syntactic processing.

56.515 **Unconscious semantic processing? No evidence for extracting the semantics of words during interocular suppression.**

Pieter Moors[1](pieter.moors@ppw.kuleuven.be), Tom Heyman[1]; [1]Laboratory of Experimental Psychology, University of Leuven

Continuous Flash Suppression (CFS) has been used as a method to probe unconscious processing of visually suppressed stimuli. One line of research pertains to the extent to which semantic information of words is processed in the absence of awareness. Since CFS was introduced, it has been reported that neutral words break suppression faster than negative words (Yang and Yeh, 2011) (and vice versa (Sklar et al. , 2013)) and that congruent prime-target relations influence suppression time (Costello et al., 2009), but do not influence electrophysiological correlates of semantic congruency (Kang et al., 2011). In this study, we used the breaking CFS paradigm to probe whether words break suppression faster than pseudo words and whether suppression time of words is influenced by its word frequency. In all experiments, participants were instructed to indicate the location of the initially suppressed words as fast as possible upon breakthrough. In Experiment 1, we found neither evidence for word type (real vs. pseudo words) nor word frequency influencing suppression time. In Experiment 2, we scrambled pseudo words to eliminate readability of pseudo words, included an inverted condition (to control for familiarity) and used a test-retest design (to examine the consistency of suppression times). Again, no effect of word type nor word frequency was found. Moreover, no effect of inversion was found and test-retest reliability was low. A control experiment was conducted to verify that reliable data could be obtained with this CFS paradigm. The target was a white disc of which the radius was manipulated. Bigger discs broke suppression faster than smaller discs indicating a basic stimulus manipulation can indeed yield reliable results in the predicted direction. In conclusion, our results provide no evidence for the extraction of semantic information in the absence of awareness induced by interocular suppression.

Acknowledgement: Research Fund - Flanders

56.516 **Hearing melody modulates perceptual dominance of musical scores during binocular rivalry**

Minyoung Lee[1](minyounglee629@gmail.com), Sujin Kim[1], Chai-Youn Kim[1]; [1]Department of Psychology, Korea University

Two dissimilar images viewed dichoptically compete for perceptual awareness, with perception alternating spontaneously over time. Dubbed binocular rivalry, this phenomenon is a useful means for manipulating and thereby studying conscious visual awareness (Blake & Logothetis, 2002). Previous studies showed that information within other sensory modalities can influence perceptual dominance of related visual stimuli during binocular rivalry (Lunghi et al., 2010; van Ee et al., 2009; Zhou et al., 2010). The current study investigated the influence of audiovisual integration on binocular rivalry dynamics by exploiting auditory musical melodies and visual musical scores. Observers viewed one of seven scores scrolling from right to left within a viewing window and a grating moving in the opposite direction dichoptically. On "congruent" trials, observers also heard the melody signified by the score; on "incongruent" trials, they heard a different melody from the one signified by the score; on "no sound" trials, only visual stimuli were presented. Observers were divided into two groups depending on whether they were instructed to read scores actively and rehearse the melody while tracking rivalry ("with instruction" group) or they were instructed simply to track rivalry ("without instruction" group). In addition, observers unable to read musical scores were also tested. In both "with" and "without instruction" groups, musical scores predominated over the grating significantly more in "congruent" trials compared to "incongruent" or "no sound" trials, an effect driven by longer dominance durations on "congruent" trials. The instruction manipulation did not influence the difference between congruent and incongruent conditions. For participants unable to read music, auditory melodies had no effect whatsoever on binocular rivalry. These results imply that learned associations between structured auditory information and abstract visual representations of that information can impact binocular rivalry dynamics.

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56.517 **Dominance of apparent motion in binocular rivalry is modulated by crossmodal synchrony**

Daniela Etchegaray[1](emmanuelguz@gmail.com), Laura Ortega[1], Jin Hak Kim [1], German Palafox[1], Emmanuel Guzman-Martinez[1]; [1]Universidad Nacional Autonoma de Mexico

Previous studies show that visual motion perception can be altered by auditory stimuli; for example, a sound burst in phase with a virtual visual collision can bias the perception of motion (Rosenthal et al., 2009). In relation to shape perception, Plass et al. (2013), showed that crossmodal interactions biased awareness in a binocular rivalry setup. Here we investigated if auditory-visual synchrony plays a role in crossmodal awareness of visual motion using a CFS task. We presented to the non dominant eye a clockwise-rotational apparent motion display at a10 Hz frame rate (producing robust apparent motion), and a mondrian composed of random pieces of the apparent motion display to the dominant eye. Participants reported if they perceived either the coherent motion or the mondrian in 7 seconds trials under four conditions: synchronous (a 10 ms burst of white noise was in phase with the frame rate); asynchronous (the burst was in antiphase with the frame rate); no sound (no burst was presented); and catch trials (simulated rivalry). We

Tuesday PM

found that dominance of apparent motion is boosted when synchronized with a sound burst; when the sound is asynchronous with the motion display, dominance is similar to the no sound condition. These results suggest that timing is an important factor in awareness of crossmodal binding.

56.518 Feature-selectivity is common in perceptual suppression phenomena

Mark Vergeer[1](mark.vergeer@ppw.kuleuven.be), Raymond van Ee[1], Johan Wagemans[1]; [1]Laboratory of Experimental Psychology, University of Leuven (KU Leuven), Belgium

Perceptual suppression phenomena are frequently used to study the concept of consciousness in general and, more specifically, the mechanisms involved in perceptual selection. We previously obtained evidence for feature-selectivity in binocular suppression (Vergeer and van Lier, Vis Res 2010). In the current study, we are interested in common mechanisms underlying monocular and binocular suppression by focusing on feature-selectivity in Motion-induced Blindness (MiB) and classic perceptual fading. In both paradigms, a peripherally presented target disappears perceptually after prolonged fixation. In perceptual fading the target is commonly presented on a static homogenous background, whereas in MiB competition for awareness occurs between a static target and a dynamic mask moving across the visual field, although they never physically overlap. Both phenomena can be influenced by neural adaptation and perceptual grouping (i.e., 2 targets disappear more often simultaneously when they are grouped, by color for instance). However, in grouping effects like these, as in binocular rivalry, it is difficult to distinguish the role of attention from a possible intrinsic stimulus-selective suppression mechanism. In both tasks, a peripherally presented oriented Gabor was removed from the screen after its perceptual disappearance and a test grating appeared left or right of the previous target location. For both phenomena, an adaptive QUEST procedure revealed significant elevated contrast detection thresholds (>10% and >20% for MiB and perceptual fading, respectively) when the test and target stimuli had the same orientation compared to when they were orthogonal, indicating feature-specificity. These results emphasize the similarity between different monocular and binocular bistable phenomena. We argue that common perceptual mechanisms are in place at the monocular and the binocular level.

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56.519 Meaningful actions and interactions receive priority in conscious perception

Junzhu Su[1](junzhusu@ucla.edu), Jeroen van Boxtel[1,2], Hongjing Lu[1,3]; [1]Department of Psychology, UCLA, Los Angeles, USA, [2]School of Psychology & Psychiatry, Faculty of Medicine, Nursing and Health Sciences, Monash University, Clayton Campus, Victoria, Australia, [3]Department of Statistics, UCLA, Los Angeles, USA

Perceiving actions and social (inter)actions is of prime importance in our everyday lives. However, it remains unclear whether natural actions and meaningful interactions between actors receive primary access to conscious perception. We investigated perceptual rivalry between conflicting point-light actions presented one to each eye to assess how visual dominance can be modulated by action processing. In Experiment 1, two dichoptically overlapping point-light dancers (upright and inverted) were presented, one to each eye and in different colors. Participants were asked to indicate the color of the more visible actor during the 20s viewing period. The proportion of dominance for the upright dancer color was greater than that of the inverted dancer, confirming that perceptual grouping of biological motion enhances visual dominance of natural actions. In Experiment 2, rivalry was induced between a male salsa dancer, and a non-salsa action. Observers viewed these rivaling actions either with or without a binocularly visible female salsa dancer, engaged in a salsa dance with the male dancer of the rivalling pair of actors. In the presence of a female dance partner, we found that the reported dominance proportion of her partner dancer was significantly greater than of the non-salsa action. Experiment 3 used the same rival actions with either a female dance partner or an unrelated male salsa dancer (from a different motion clip) presented binocularly in green. In addition to reporting the dominance color during the viewing period, participants decided whether green actors interacted with other actors at the end of each trial. We found that identification of interactive actions further promotes visual dominance of relevant actions. These results indicate that awareness during binocular rivalry is partly governed by the activity of high-level perceptual mechanisms specialized for processing biologically significant cues, such as biological motion and social actions that modulate ocular suppression via cortical feedback.

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56.520 Perception during binocular rivalry is biased by the content of visual working memory.

Surya Gayet[1](s.gayet@uu.nl), Jan Brascamp[1], Stefan Van der Stigchel[1], Chris Paffen[1]; [1]Helmholtz Institute, Utrecht University, Department. of Experimental Psychology.

During binocular rivalry, dissimilar images presented dichoptically compete for conscious expression. Here, we investigate how the content of visual working memory (VWM) affects the competition between two images engaged in binocular rivalry. Trials in our experiments consisted of three phases: first, two colored patches, each taken from a different color category, were briefly presented, followed by an arrow cue indicating which of the two colors should be memorized for subsequent recall. Second, two orthogonal square-wave gratings, one gray and one colored, were presented dichoptically for 10 seconds. Participants were instructed to continuously report the orientation of the perceived grating (tilted clockwise or counterclockwise). In the third phase, three stimuli of slightly different hues were presented, and participants were required to select the memorized color. We analyzed perceptual dominance separately for trials where the color of the chromatic grating matched either (A) the memorized color, (B) the presented but discarded color and (C) a third unrelated color. The grating of the memorized color (A) and, to a lesser extent, of the discarded color (B) both enjoyed more perceptual dominance than their gray counterparts. However, only in the memorized condition (A) was this dominance imbalance larger than that in the unrelated color condition (C). Our results show that dominance durations during binocular rivalry were biased towards the stimulus matching the color held in VWM. Nonetheless, we advocate caution in the generalization of these findings, as a number of follow up experiments demonstrate that competition between more similar stimuli (i.e., both chromatic) is unaffected by the content of VWM. We conclude that the content of VWM has the potency to bias ocular dominance, but that further experimentation is required to get a complete grasp on the interaction between the content of VWM and perceptual dominance during binocular rivalry.

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56.521 Evidence for solid perception of binocular rivalry under top-down influences of visual working memory

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It is widely believed that binocular rivalry is resolved by top-down influences that bias a momentary selection towards either of the two rival images. In our previous study, we observed a pattern of results supporting such a top-down account, where the rivalry appears to be resolved by information held in visual working memory (VWM). However, recent neural findings suggest that binocular rivalry occurs during the early visual processes of feedforward sweeps, presuming a minimal role of top-down influences. In this study, we tested the alternative bottom-up account by addressing whether the rivalry sensation is distinct, even under the influence from VWM. In the experiments, participants remembered the colors of 2, 4, and 6 binocularly displayed items (memory array) and then compared their colors with those in the next binocular display (test array). In half of the trials, the memory and test displays were identical (i.e., no-change), whereas the remainder were divided into three trial-types. An item in the test display mismatched the memory array by (1) binocular mismatches (i.e., standard change), (2) a monocular mismatch (i.e., rivalry), or (3) a monocular mismatch with the other binocular test item missing (i.e., blank-rivalry). The participants also categorized each trial based on distinct sensation upon the test display. The results demonstrated that both the standard and blank-rivalry trials yielded patterns of a setsize effect, apparently derived from the memory accuracy decline along the setsizes, while the rivalry trials yielded a relative lack of the setsize effect. Moreover, trial categorization responses revealed that the participants were explicitly able to tell the sensation of the rivalry from the standard change or the blank-rivalry occurrence. These results suggest that binocular rivalry can occur from rival stimuli per se, while resisting top-down influences from VWM, and support bottom-up account for rivalry occurrence and its phenomenological consequence.

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 See page 3 for Abstract Numbering System

56.522 **What determines the influence of attention on binocular rivalry?** Kevin C Dieter[1,2,3,4](kevin.dieter@vanderbilt.edu), Michael D Melnick[3,4,5], Duje Tadin[3,4,5]; [1]Vanderbilt Vision Research Center, Vanderbilt University, Nashville, TN, USA, [2]Department of Psychology, Vanderbilt University, Nashville, TN, USA, [3]Center for Visual Science, University of Rochester, Rochester, NY, USA, [4]Department of Brain & Cognitive Sciences, University of Rochester, Rochester, NY, USA, [5]Department of Opthalmology, University of Rochester, Rochester, NY, USA

INTRODUCTION: Binocular rivalry is relatively resistant to contextual and/or attentional modulations, distinguishing it from other forms of visual bistability that are readily influenced by attention or context. What explains this difference? Drawing from our recently developed framework (Dieter & Tadin, 2011), we predicted that the temporal dynamics of visual competition during rivalry determine the efficacy of attentional influences over rivalry. Specifically, we hypothesized that rivalry would be susceptible to attentional influence only during periods of unresolved conflict: at rivalry onset and near the end of individual rivalry percepts (Alais et al., 2010). Indeed, attention strongly affects initial rivalry (Mitchell et al., 2004), but there has been no work examining the temporal specificity of attentional effects during continuous rivalry. METHODS: Because percept durations during binocular rivalry are stochastic, we could not cue attention at a set time. Instead, while observers continuously viewed rival gratings, we occasionally presented transient, feature-based attentional cues with variable SOAs relative to the start of each percept. This ensured that some percepts were cued near their start, and some near their end. To establish whether these cues influenced observers' perceptions, we compared dominance durations of cued percepts with their expected duration (based on un-cued percept durations). RESULTS: Attentional cues influenced percept durations in a content-specific manner. Cues whose features matched the currently dominant stimulus led to a 5% increase in percept duration ($p < 0.05$), while cues matched to the currently suppressed stimulus shortened percepts by almost 20% ($p < 0.01$). Crucially for our hypothesis, analyses of the temporal aspect of attentional effects in our experiment revealed that cues influenced perception only when presented during the final second of a percept's dominance. Cues presented earlier had no influence. This indicates a temporally isolated effect of attention that corresponds to periods of unresolved competition during binocular rivalry.

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56.523 **Effect of attention on the initiation of binocular rivalry**

Yaelan Jung[1](jung.yaelan@gmail.com), Min-Suk Kang[2], Sang Chul Chong[1,3]; [1]Graduate Program in Cognitive Science, Yonsei University, [2]Department of Psychology, Sungkyunkwan University, [3]Department of Psychology, Yonsei University

Recent studies indicate that attention influences or even enables the alterations in perception when two different images engaged in binocular rivalry (Brascamp & Blake, 2012; Zhang et al., 2011). If attention is necessary for two different items to undergo binocular rivalry, it is possible that attention facilitates one of the competing images to achieve dominance over the other. Here we tested this prediction by measuring proportion of mixed dominance in the initial phase of binocular rivalry. In Experiment 1, four, equally spaced concentric rings were rotated along an imagery circle for two seconds while the center of each ring was flickered with different colors. Participants' attention was manipulated by asking them to track two rings located in the opposite sides and to detect a cued color while ignoring the other two rings. Rival stimuli were then presented one of those four locations, resulting in that the rival stimuli occupied either one of the two attended locations (attended condition) or one of the two unattended locations (unattended condition). We compared the proportion of mixed dominance between the attended and unattended conditions while varying the duration of rival stimuli from 50 ms to 1050 ms. As a result, the proportion of mixed dominance was significantly smaller in the attended condition than in the unattended condition when the rival stimuli lasted for 300 ms. In Experiment 2, we replicated Experiment 1 with finer stimulus durations from 50 ms to 350 ms (the interaction between the stimulus duration and attention was statistically significant). These results suggest that attention facilitates the initiation of binocular rivalry, providing converging evidence that attention is necessary for binocular rivalry.

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Face perception: Experience, learning and expertise 2

Tuesday, May 20, 2:45 - 6:45 pm
Poster Session, Pavilion

56.524 **McGurk effect appears after learning syllables with non-facial motions.** Miyuki G. Kamachi[1], Kazuki Ohkubo[1]; [1]Faculty of Informatics, Kogakuin University

The AV combination of 'bilabial' sounds (e.g. the phoneme /ba/) and 'palatal' mouth movement (e.g. the visual articulation of /ga/) typically results in a 'fusion response', in which a new phoneme different from the originals is perceived (e.g. /da/). On the other hand, when the combination of AV is reversed, subjects basically perceive either of the phonemes of original A or V pronounced, and sometimes report the perception of the mixed phoneme, 'combination response' (e.g. /bga/ or /gba/)(MacDonald and McGurk, 1978; Omata and Mogi, 2008). Moreover, 'fusion' showed larger effect on proportion compared with 'combination' (McDonald and McGurk, 1978). Both types of response were thought to have resulted from our innate or empirical learning of facial speech motions. Here we report an experimental study to reveal whether McGurk effects arise only with facial type movement. In learning session with 1600 trials, participants viewed an object (gray-colored cube) rotating with specific direction (leftward) combined with auditory /pa/ sounds (of 5 speakers), and the same shape of the object rotating with another direction (rightward) with auditory /ka/ sounds. Rotation directions also involved weak depth rotation randomly, but had always rotated clearly toward left or right in frontal parallel plane. Participants were asked to identify each auditory stimulus by selecting one of the speech sounds /pa/, /ka/ and /ta/. In the following test session, the same visual stimuli were presented randomly combined with the same/different types of sound pronounced by the same speakers as learned ones. The proportion of responses in learning-group was compared with that of no-learning-group. Results revealed that fusion type effect was found only in the learning group, showing that non-facial motions were learned and combined as auditory speech irrespectively by the face-specific motions.

Acknowledgement: JSPS KAKENHI Grant Number 24530921

56.525 **Decoupling perceptual and response biases in a sequential face judgment task** Teresa Pegors[1,2,3](tpegors@sas.upenn.edu), Peter Bryan[1,2,3], Marcelo Mattar[1,2,3], Russell Epstein[1,2,3]; [1]Psychology Department, [2]Center for Cognitive Neuroscience, [3]University of Pennsylvania

When people make perceptual or evaluative judgments on a series of stimuli, the judgment on one trial is often influenced by the trials that came before (e.g. Matthews and Stewart 2007, Kondo et al. 2012). In such cases, it is difficult to characterize the separate influences of the previous response, the previous stimulus, or both, since these two effects are usually highly correlated. We attempted to solve this problem by creating an experimental design that allowed us to independently measure the effects of the previous stimulus and the previous response. 112 female faces were displayed sequentially for 4 seconds each. For each face, participants either made a face attractiveness or hair darkness rating on a 1-8 Likert scale. Importantly, these judgments alternated such that all attractiveness judgments were preceded by hair darkness judgments, and vice versa. Because hair darkness was uncorrelated with face attractiveness, we were able to regress the attractiveness rating in a given trial on both the previous response and previous mean face attractiveness (values for which were determined based on data from 28 independent raters). Across 30 subjects, we found that the mean attractiveness of the previous face negatively predicted the current face attractiveness judgment; in contrast, we saw no influence of the previous response. Our results suggest that the attractiveness of the previous face has a contrastive effect on the current attractiveness judgment given to a face, and that assimilative effects due to the previous response may only operate across trials of the same judgment type. The alternating design we use here offers a method for researchers to independently characterize influences due to the previous response and the previous stimulus in sequential judgment tasks.

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56.526 Effects of Exposure Frequency and Pose Variation on Learning 3-D Faces: A Comparison between Viewpoint Interpolation and Extrapolation

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A major issue in face recognition and generalization concerns how the visual system can overcome image variations caused by pose and expression to derive stable and constant representations. In their recent study, Shyi & He (2011) demonstrated the joint influence of exposure frequency and expression variation on face learning where multiple exposures coupled with sufficient number of expression variation can yield optimal performance in face recognition and generalization. Here in two experiments we extended Shyi & He's study and examined the effects of exposure frequency and pose variation on learning 3-D faces. In particular we compared how viewpoint interpolation and extrapolation might differ in their effects on face recognition and generalization. In Experiment 1, where each face was exposed for 12 times with different degree of pose variation during learning, we found relatively poor performance in recognition due to pose variation, and participants committed relatively high rate of false positives when recognizing faces that were never shown during learning. In Experiment 2, we found much better performance with rates of false positives substantially reduced when each face was exposed 24 times during learning. Most importantly, we found in both experiments that interpolated views not only yielded results comparable to single views when they were old, but also yielded better results when they were new, implicating robust viewpoint generalization due to interpolation. In contrast, extrapolated views, while also yielding modest level of generalization, the effect of generalization was much weaker than interpolated views. It is also interesting to note that, unlike the more dynamic nature of interaction between exposure frequency and expression variation (Shyi & He, 2011), the effects of exposure frequency and pose variation appears to be additive. Possible roles for viewpoint interpolation versus extrapolation in learning 3-D faces across pose variation are discussed.

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56.527 Face, the final frontier: An ERP study probing processing of human and alien faces in Trekkies and non-Trekkies

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Experience can change the face processing system in infancy (e.g., Kelly et al., 2009) and childhood (e.g., Sangrigoli et al., 2005). This flexibility is less evident in adulthood (Dufour et al., 2004), potentially due to age-related declines in plasticity. Alternatively, reduced flexibility may be due to changes in the environment that decrease the likelihood of massive, individuated experience with novel face types (see Scott & Monesson, 2009). One population that has this type of experience with novel face types, to which they likely had no exposure in early development, are fans of the science-fiction franchise Star Trek (i.e., Trekkies). To determine whether exposure to Star Trek alien faces changes the face-processing system we are comparing self-identified Trekkies' and non-Trekkies' behavioral and brain responses to Star Trek human and alien faces. Thirty-eight non-Trekkies and 5 Trekkies have been tested and recruitment is ongoing. In preliminary analyses, we found no difference in memory for human faces between the groups ($t(36) = -.067$, $p = .947$) and significantly greater memory for alien faces in Trekkies than non-Trekkies ($t(36) = 3.45$, $p = .001$). Non-Trekkies' memory performance did not significantly relate to how alien they rated alien faces to be, though there appears to be a trend in that direction ($r = -.32$, $p = .073$). We expect that Trekkies will show comparable face-specific ERP responses (N170) to human and alien faces and that non-Trekkies will show a clear difference in the N170 response to human vs. alien faces. These findings of increased specialization for alien faces in Trekkies would suggest that there remains flexibility in the adult face processing system. Future research should investigate how much experience with different face types is required to tune the adult face-processing system.

56.528 Face drawing experience is associated with better face recognition performance and reduced left-side bias in face perception

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Recent research in computer vision showed that while both analytic (local) and holistic (global) approaches perform well in face recognition, the fusion of the two yields the best performance. Professional face artists/caricaturists mastering both the drawing of individual facial features and whole faces may engage in such fused processing of faces, and thus may excel in face recognition. Zhou et al. (2012) found that art students with face drawing experience showed weaker holistic face processing than non-drawers; nevertheless, the two groups did not differ in sequential face-matching performance. Here we recruited professional face artists, in contrast to art students, in a simultaneous face-matching task with unfamiliar faces that differed in illumination, pose, disguise and expression. In contrast to sequential face-matching, our task reduces the involvement of visual short-term memory, as face artists' advantage is more likely to be in their perceptual ability than in memory. We recruited 15 face artists and 15 non-drawers. Before the experiment, participants drew a face within 15 minutes. An experienced face artist rated participants' expertise according to the drawings. We found that face artists outperformed non-drawers in the simultaneous face-matching task ($t(28) = 2.56$, $p <.05$). Face drawing expertise was positively correlated with face recognition performance ($r = 0.38$, $p <.05$). In addition, while non-drawers judged a face made from two left half-faces more similar to the original face than one from two right half-faces, i.e., the left side bias (right hemisphere dominance) in face perception, face artists had a reduced bias than non-drawers ($t(28) = -2.39$, $p <.05$), suggesting reduced global face processing. Face drawing expertise was negatively correlated with the bias ($r = -0.47$, $p <.05$). Together, the results suggest that face drawing expertise may shift attention from global to local, which may help face recognition in challenging tasks.

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56.529 On the other side of the fence: The effects of social categorisation and spatial arrangement on memory for own-race and other-race faces.

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The term „own-race bias" (ORB) refers to the phenomenon that humans are better at recognising faces from their own than a different ethnic group. The perceptual expertise account assumes that our face perception system has adapted to the faces we are typically exposed to, making it poorly equipped to process other-race faces. Social categorisation accounts assume that other-race faces are initially categorised as out-group, decreasing motivation to individuate them. Supporting social categorisation accounts, a single study has reported improved recognition for other-race faces categorised as belonging to the participants' own university (Hehman et al., 2010). Faces were studied in groups, containing both own-race and other-race faces, half of each labeled as in-group and out-group, respectively. When study faces were spatially grouped by ethnicity, participants showed a clear own-race bias. When faces were grouped by university affiliation, recognition of other-race faces from the social in-group was indistinguishable from own-race face recognition. The present study aimed at replicating and extending this finding. Forty Asian and 40 Caucasian participants studied Asian and Caucasian faces for a recognition test. Faces were presented in groups, containing an equal number of own-university and other-university Asian and Caucasian faces. Between participants, faces were either grouped according to race or university affiliation. Eye tracking was used to study the the distribution of spatial attention to individual faces in the display. Replicating Hehman et al. (2010), participants in the race grouping condition showed a clear ORB in memory. However, participants in the university grouping condition showed the same bias. Face memory was unaffected by university affiliation and spatial grouping, although some effect on response criterion (C) suggests that these experimental manipulations were generally effective. Eye tracking revealed strong looking biases towards both own-race and own-university faces. Results are discussed in light of the theoretical accounts of the own-race bias.

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56.530 Face Race Affects Various Types of Face Processing, but Affects Them Differently

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Previous studies have shown that face race influences various aspects of face processing, including face identification (Meissner & Brigham, 2001), holistic processing (Michel et al., 2006), and processing of featural and configural information (Hayward et al., 2008). However, whether these various aspects of other-race effects (ORE) arise from the same underlying mechanism or from independent ones remain unclear. To address this question, we measured those manifestations of ORE with different

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tasks, and tested whether the magnitude of those OREs are related to each other. Each participant performed three tasks. (1) The original and a Chinese version of Cambridge Face Memory Tests (CFMT, Duchaine & Nakayama, 2006; McKone et al., 2012), which were used to measure the ORE in face memory. (2) A part/whole sequential matching task (Tanaka et al., 2004), which was used to measure the ORE in face perception and in holistic processing. (3) A scrambled/blurred face recognition task (Hayward et al., 2008), which was used to measure the ORE in featural and configural processing. We found a better recognition performance for own-race than other-race faces in all three tasks, confirming the existence of an ORE across various tasks. However, the size of the ORE measured in all three tasks differed; we found no correlation between the OREs in the three tasks. More importantly, the two measures of the ORE in configural and holistic processing tasks could not account for the individual differences in the ORE in face memory. These results indicate that although face race always influence face recognition as well as configural and featural processing, different underlying mechanisms are responsible for the occurrence of ORE for each aspect of face processing tested here.

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56.531 They all look different to me: Within-person variability affects identity perception for other-race faces more than own-race faces

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People are worse at recognizing other-race faces than own-race faces. This other-race effect (ORE) has been attributed to worse discrimination of other-race faces, as reflected in the phrase "they all look the same to me". A neglected challenge in face recognition has been the ability to recognize a face's identity across superficial changes (e.g., expression, hairstyle). Indeed, even for own-race faces, photos of the same person can be perceived as belonging to different individuals, unless that person is familiar (Jenkins et al., 2011). We investigated how within-person variability affects our perception of identity for own and other-race faces. Caucasians (n=49) were given 40 photographs of two unfamiliar people (20 photographs/model) and asked to sort them into piles such that each pile had all of the pictures of one person. The photos were either of own-race (UK celebrities) or other-race (Chinese celebrities) faces. Participants had more difficulty discriminating other-race faces; more participants put two different people into the same pile for other-race (92%) than own-race (63%) faces. Notably, participants sorted the photographs into significantly more identities for other-race (M = 10.96; range = 4 to 31) than for own-race faces (M = 4.79; range = 2 to 16: Cohen's d =1.18). It is unlikely that the smaller number of piles for own-race faces reflects less variability among the Caucasian photographs. In an ongoing study, Chinese participants (to date, n = 6) sorted the Caucasian photographs into an average of 15 identities (range = 8 to 20). These findings suggest that studies in which the same image of a face is used for presentation and test may under-estimate the challenge of recognizing other-race faces. In the real world it may be the case that 'they all look different to me'.

56.532 Evidence for a Perceptual-to-Social Transition in Infant Categorization of Other-Race Faces

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Prior research has investigated how infants categorize same- versus other-race faces, but not how infants represent different classes of other-race faces. For example, Anzures, Quinn, Pascalis, Slater, and Lee (2010) examined how Caucasian 6- to 9-month-olds categorized Caucasian versus Asian faces. Six-month-old performance was dominated by a spontaneous preference for own-race faces. Nine-month-olds habituated to Caucasian or Asian faces generalized habituation to novel instances from the familiarized category and dishabituated to novel category instances. The results indicate that 9-month-olds form distinct category representations for own- versus other-race faces, but leave open the question of how different classes of other-race faces are represented. That is, we do not know if infants respond categorically to the perceptual distinctions between different classes of other-race faces or if infants represent other-race faces more socially as a broad out-group class. The current study therefore used a familiarization/novelty-preference procedure to investigate formation of category representations for faces from two other-race classes (Asian vs. African) by Caucasian 6- and 9-month-olds. Both age groups were familiarized with Asian or African faces and tested with novel Asian versus novel African faces. Six-month-olds generalized looking time responsiveness to novel instances from the familiarized category and preferred novel category instances. However, 9-month-olds did not prefer novel category instances. Moreover, in a control experiment, Caucasian 9-month-olds familiarized with Caucasian or other-race faces (Asian or African) and tested with novel Caucasian versus novel other-race faces preferred novel category instances, replicating Anzures et al. The results indicate that while Caucasian 6-month-olds categorically represent the distinction between African and Asian faces, Caucasian 9-month-olds form a broad other-race category inclusive of African and Asian faces, but exclusive of own-race Caucasian faces. The findings suggest that infants initially categorize other-race faces on a perceptual basis and subsequently represent those faces on a more social (i.e., out-group) basis.

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56.533 The Effect of Early Visual Deprivation on the Development of Judgments of Attractiveness

Larissa Vingilis-Jaremko[1,2](vingilln@mcmaster.ca), Daphne Maurer[1]; [1]McMaster University, [2]York University

Adults find averaged faces that approximate the population mean to be more attractive than most other faces (Langlois & Roggman, 1990). By 3 months, infants appear to be able to form an average of faces they just saw (de Haan et al., 2001), but the influence of averageness on attractiveness judgments does not become as strong as in adults until after age 9 (Vingilis-Jaremko & Maurer, 2013). We investigated the importance of early visual experience by taking advantage of a rare condition: adults who were born with bilateral cataracts that blocked all patterned visual input until they were removed in the first year of life and the patient was given compensatory contact lenses. These adults experienced a period of visual deprivation during a sensitive period early in life for the development of many aspects of vision. We presented participants with pairs of faces that had been transformed toward and away from an average face of the same sex and asked them on each trial to select which face was more attractive. Averageness influenced the attractiveness judgments of adults treated for bilateral congenital cataracts, but to a lesser extent than in adults with normal vision. The data suggest that visual input early in life is necessary to set up the neural architecture that underlies the influence of averageness on adults' perception. That influence may be related to the establishment of a multi-dimensional 'face space' centred on a prototype face that is the mean of one's cumulative experience with faces (Valentine, 1991). The results are consistent with findings that cataract-reversal patients show less differentiation of upright and inverted faces (Le Grand et al., 2001) and have smaller-than-normal identity aftereffects. Together, the data suggest that early visual experience is necessary to form a normal face space centered on a veridical norm

56.534 No country for old men: Mental representations of age reveal two categories (young and old) in young observers, but three (young, middle aged and old) in old observers.

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Categorizing the age of others is a process so automatic and ubiquitous that we are rarely aware of it. On what basis does the brain make these perceptual judgments? We used the 'superstitious perception' reverse correlation paradigm (Gosselin & Schyns, 2003, Mangini & Biedermann, 2004) to address this question with faces. 12 observers with normal or corrected to normal vision (six 18-25; six 58-75 years old) participated in the experiment. On each trial, stimuli comprised an average face (averaged over 83 faces, 18 to 79 years old) with superimposed noise generated from recursive Gabor filters (Morlet wavelets of size 5, 6 orientations, 2 polarities). We instructed observers that they would be categorizing ages faces drawn from a large database, and obscured by noise. At the start of each block of 18 trials, observers choose one of 3 simultaneously presented stimuli (computed as above) as the best representative of a numerical age category (18-35, 40-55, or 60-80 years old), randomized across blocks over a total 3,240 trials. For each numerical age category, we reverse correlated the noise templates. Features associated with 'old' images were a low spatial frequency darkening of the skin and thin lips, while 'young images' showed paler skin, round cheeks and exaggerated lips. In the image domain, we validated these features with a pattern classifier, revealing the low SF pale/dark skin as a discriminatory feature of young/old face-images. In the perceptual domain, 8 independent observers validated the CIs (projected onto 12 new average faces), by classifying their age. We identified an 'other-age effect' in young observers: Young observer classification images (CIs) for

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'middle aged' were not distinct from those of old, whereas old observers had distinctive CIs for the three age categories. Validation demonstrated that older observers' CIs more accurately spanned the expected age range.

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56.535 **Classification images characterize age-related deficits in face discrimination** Sarah E. Creighton[1](creighs@mcmaster.ca), Patrick J. Bennett[1], Allison B. Sekuler[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University

Face perception is impaired in older adults, yet the cause of this decline is not well understood. Here we studied age-related changes in face perception using the random sub-sampling variant of the classification image (CI) method described by Nagai et al. (Vision Res, 2013). We obtained CIs for six older and eight younger observers performing a face discrimination task: Each trial presented a target face + noise, and observers indicated which of two faces they had seen. Noise contrast was adjusted using a staircase procedure maintaining ~71% correct, and observers completed two sessions (2900 trials total). As in previous studies (Sekuler et al, Cur Biol, 2004), younger observers consistently relied on pixels in the eye/brow region, and that strategy generally was apparent after just one session. Older adults demonstrated reduced sensitivity (higher contrast thresholds), made less efficient use of informative face regions (lower cross-correlations with the ideal template), and had CIs that differed qualitatively from younger observers. For example, only one older observer relied on the eye/brow region as heavily as younger observers, and most older observers showed no obvious structure in their CIs, even after two sessions. Greater individual differences also were observed for the older group: One observer with a high cross-correlation and low contrast threshold had no evident structure in the CI; while another showed a CI qualitatively similar to younger observers, yet had a low cross-correlation and high contrast threshold. Importantly, sensitivity and efficiency were correlated for older observers, suggesting the CI method captures older observers' perceptual strategy. The lack of consistent structure in older observer's CIs may result from increased variability in response strategy, an hypothesis we currently are testing using the response consistency method. Overall, our results are consistent with an age-related qualitative change in face processing.

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56.536 **The Influence of Face Processing Biases on Eye Gaze Following and Object Processing During Infancy** Charisse B. Pickron[1](cpickron@research.umass.edu), Eswen Fava[1], Lisa S. Scott[1]; [1]University of Massachusetts, Amherst

Following eye gaze provides perceivers opportunities to learn about events which their social partner is referencing. Eye gaze following influences the way infants process cued versus uncued targets. Recent work has found that affect (e.g., fear) as well as individual familiarity (e.g., primary caregiver) of faces can increase or decrease attention allocated toward cued versus uncued targets (Gredebäck et al., 2010; Hoehl, Wahl et al., 2012; Hoehl, Wiese, & Striano, 2008). However, eye gaze following has not been examined within the context of face-processing biases. During infancy face-processing biases develop such that 6-month-old infants differentiate among faces within unfamiliar or infrequently experience groups (e.g., other races) that neither 9-month-old infants nor adults readily differentiate. However, it is currently unclear whether the progression of face-processing biases influences the development of eye gaze following and object processing. In the present investigation, 5- and 10-month-old infants completed an eye-tracking task in which they viewed videos of adults, who varied by race and gender, cue one of two objects through shifts in eye gaze. After objects appeared with each face, they were presented in a preferential looking task. Infants' looking patterns towards these events were examined. Preliminary results suggest that changes in attention toward cued versus uncued objects between 5 and 10 months are influenced by both the race and gender of the cuing face. Five-month-old infants displayed significant and marginally significant differences between cued and uncued objects for both frequently and infrequently experienced races (respectively). However, by 10 months, infants only differentiated between objects after being cued with a face from an infrequently experienced group. Moreover, at 5 months the gender of the face significantly influenced attention to the objects; but not at 10 months. These results provide insight into how early experiences with particular groups influence infants' processing of social communication cues.

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56.537 **Betty White versus Scarlett Johansson: Examining Consensus in Attractiveness Judgments for Young and Older Adult Faces** Lindsey Short[1](ls08ts@brocku.ca), Harmonie Chan[1], Anne Hackland[1], Catherine Mondloch[1]; [1]Department of Psychology, Brock University

We recently reported that young and older adults are more sensitive to deviations from normality in young than older adult faces, suggesting that the dimensions of face space are optimized for the face age category to which we are most frequently exposed throughout life (Short & Mondloch, 2013). Here we report two studies designed to a) investigate the implications of our previous finding for attractiveness and age judgments of naturally varying faces (Experiment 1), and b) examine the development of this differential sensitivity during childhood (Experiment 2). In Experiment 1, young adults (n = 40) estimated 40 young and 40 older faces' age and attractiveness. There was more between-participant variability (i.e., less consensus) in both attractiveness ratings and age judgments for older than young faces, ps <.01. Furthermore, only for older faces was attractiveness correlated with perceived (but not actual) age, p <.05. These results further suggest that young adults' norm(s) is less well refined for older than young faces; we are currently testing older adults to examine whether extensive experience with older faces moderates this effect. In Experiment 2, seven-year-old children (n = 29) were shown young and older face pairs; one member of each pair was undistorted and the other had compressed (-50%) or expanded (+50%) features. Children indicated which member of each pair was more attractive. Similar to young and older adults, 7-year-olds were more accurate in detecting distortions in young than older faces, p <.05. We are currently testing 3-year-olds, and results to date (n = 15) suggest that like 7-year-olds, 3-year-olds are more accurate for young (73% correct) than older faces (63% correct). These results suggest that differential experience with young relative to older faces early in life is sufficient to tune children's perceptual systems to the dimensions of young adult faces.

Acknowledgement: NSERC, Vanier CGS

Face perception: Social cognition

Tuesday, May 20, 2:45 - 6:45 pm
Poster Session, Pavilion

56.538 **Rapid spatial perspective taking for obstructed views** Lewis Baker[1](lewis.j.baker@vanderbilt.edu), Daniel Levin[1]; [1]Department of Psychology & Human Development, Peabody College, Vanderbilt University

Developmental research has demonstrated infants' ability to monitor goals and intentions as early as 8 months old, yet research consistently reveals that adult perspective taking is cognitively effortful and error prone. Several recent studies have tested a two-system theory, whereby a relatively quick, heuristic process tracks the basic visuospatial perspective of others, while a relatively slow, effortful process selects and evaluates the belief states leading to higher-level theory of mind. However, experiments supporting two systems have consistently equated spatial perspective taking with gaze direction. In a psychophysical paradigm, participants were rapidly cued to take their own or an avatars' perspective, and judged whether that perspective could see a number of objects within the range of subitization. In some trials, the avatar's view was obstructed by a barricade. Reaction time and error rate rose significantly when self and other views conflicted, even when taking one's own perspective. Results support a heuristic mechanism that quickly assess the content of another's perspective.

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56.539 **Unconscious Processing of Direct Gaze: fMRI Evidence** Lan Wang[1], Zhentao Zuo[1], Peng Zhang[1], Sheng He[1,2]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Biophysics, Chinese Academy of Sciences, Beijing, China, [2]Department of Psychology, University of Minnesota, Minneapolis, Minnesota, United States of America

Humans are sensitive to others' gaze direction. Evidence from a behavior study using continuous flash suppression (CFS) suggests that faces with direct and averted gaze are processed differently before they reach conscious awareness (Stein et al. 2011). An ERP study showed that invisible faces with direct gaze elicited significantly larger negative deflections at 200, 250, and 300 ms over the parietofrontal electrodes (Yokoyama et al. 2013). These results suggest that faces with direct gaze are preferentially processed in the brain unconsciously. In the current fMRI study we investigated whether brain regions involved in face and gaze processing were sensitive to gaze information rendered invisible through CFS. With a slow event-related design, four types of stimuli were presented to observers: visible and invisible faces with direct and averted gaze. The four conditions were shown in

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random order in each scan session, and observers were instructed to press a button to indicate when they saw a face. To minimize the physical difference between the two visibility conditions and to mimic the perception when faces leak from CFS in the invisible conditions, the same kind of noises were blended in the same eye with faces in the visible trials. Data from observers who saw any face during invisible trials were excluded from analysis. Results show that although signals from invisible faces were significantly reduced relative to visible faces, a number of brain regions, including the OFA, FFA, and the amygdala, responded differentially to invisible faces with direct vs. averted gazes. STS also responded moderately, but more variably, to invisible faces. There was a tendency for the invisible faces with the direct gaze to elicit stronger responses than invisible faces with an averted gaze; a tendency not observed for visible faces. Our results provide the neural correlates for the unconscious processing of gaze information.

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56.540 **Join my attention by looking at my back: The back of head orientation can serve as both supraliminal and subliminal orienting cues** An-Yi Chang[1](b96207015@ntu.edu.tw), Su-Ling Yeh[1,2,3]; [1]Department of Psychology, National Taiwan University, Taipei, Taiwan, [2]Neurobiology and Cognitive Neuroscience Center, National Taiwan University, Taipei, Taiwan, [3]Graduate Institute of Neuroscience, National Taiwan University, Taipei, Taiwan

Viewing someone's gaze or head orientation frontally induces the viewer's joint attention by shifting attention to where the gaze or head is oriented. The present study investigated whether viewing the back of an averted head will induce attentional shift as it does in the front view. The Posner cueing paradigm was adopted using images of the backs of heads as orienting cues that were presented visibly (Experiment 1) or invisibly (Experiment 2) by using a backward masking paradigm. The head images looked to the left or right side. The target – tilt grating – appeared on the faced-to side (valid cue) or the opposite side (invalid cue). Participants were asked to indicate the tilt orientation of the grating by pressing buttons with their left or right hand. Results showed that both the supraliminal (Experiment 1) and subliminal (Experiment 2) valid cue facilitated the response to target, suggesting that the back of an averted head also guides our attention. Moreover, we also found a cue-response compatible effect: when the response hand was congruent with the cued side, the reaction time was significantly faster than in the incongruent condition. This is the first study demonstrating attentional orienting by the back of averted heads regardless of awareness. Furthermore, the back of head orientation not only orients our attention but also facilitates the action of the related side.

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56.541 **What are you looking at?: The acuity of joint attention** Tao Gao[1](taogao@mit.edu), Joshua Tenenbaum[1], Nancy Kanwisher[1]; [1]Brain and Cognitive Sciences, MIT

How accurately can you determine what another person is looking at? This ability is essential for joint attention, a core, early-developing form of social interaction. While it has been shown that people can accurately determine whether another person is looking directly at them versus away, little is known about our ability to determine where another person is looking when their gaze is directed away from us. We measured subject's accuracy in 'reading" another person's gaze in a study that met three criteria: (1) subjects viewed another person's natural looking behavior live while that person (the "Actor") gazed at experimenter-indicated objects (2) without any constraint on head and eye movements and (3) in a crowded display containing many objects. We used a Kinect sensor to capture Actors' head movements for modeling the target's gaze behavior. In our "what-are-you-looking-at" task, the Actor gazes at one of 52 objects arrayed on a table in an arc around the Actor. In each trial, the Actor gazes at a different object for 9s. Our participants seated on the opposite side of the table to decide which target the Actor is looking at. Objects are spaced 10° apart in the Actor's visual angle. Our results indicate that: (1) Participant's accuracy of choosing the exactly correct object is about 40%, suggesting a limit on the acuity of joint attention; (2) Observers' incorrect responses are not random, but are systemically biased toward certain regions of the actor's visual field; (3) Individual observers differ reliably from each other in their accuracy, which ranges from 20%~60%; (4) The difference in readability of each Actor's gaze can be largely explained by the variance of the head movements recorded by the Kinect sensor. These results collectively reveal the acuity of joint attention by showing its limit, bias and variance.

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56.542 **Unconscious processing of eye gaze direction in the human brain** Marcus Rothkirch[1](marcus.rothkirch@charite.de), Apoorva Rajiv Madipakkam[1,2], Philipp Sterzer[1,3]; [1]Visual Perception Laboratory, Department of Psychiatry, Charité - Universitätsmedizin Berlin, Berlin, Germany, [2]International Program Medical Neuroscience, Charité – Universitätsmedizin Berlin, Berlin, Germany, [3]Bernstein Center for Computational Neuroscience, Berlin, Germany

Faces convey a wealth of information critical for the guidance of behavior in social contexts. Therefore, in the human brain a highly specialized network is dedicated to the rapid and efficient processing of facial information. A number of previous studies have shown that parts of this network can process salient facial features, such as emotional expressions, even without awareness. In contrast, it has remained largely unknown, whether face-responsive brain regions can also process the direction of another's gaze – a highly relevant signal for social interactions – unconsciously. To this end, we conducted a functional magnetic resonance imaging study in which faces were presented whose gaze was either directed towards or away from the observer. Face stimuli were either presented visibly or rendered invisible through interocular suppression. Participants' awareness of the faces was probed by a confidence rating and a two-alternative forced-choice (2AFC) task regarding the spatial location of the face on each trial. Only trials in which participants reported unawareness of the face stimuli in the confidence rating were taken into account. Despite subjective reports of unawareness, one half (N = 9) of the participants performed above chance in the 2AFC task, while the other half performed at chance level. For both these subgroups, we observed gaze-specific neural responses in the fusiform face area (FFA), superior temporal sulcus (STS), and amygdala, which have previously been shown to be involved in the processing of eye gaze of visible faces. In all three regions activations for averted gaze was higher compared to direct gaze. Our results demonstrate a sensitivity of the human brain to other people's eye gaze direction, even when the observer is unaware of their faces. This underlines the high relevance of this facial information for human social interactions.

56.543 **The Opioid System Promotes Gaze to the Eyes** Olga Chelnokova[1](o.v.chelnokova@psykologi.uio.no), Bruno Laeng[1], Jeppe Riegels[1], Guro Løseth[1], Marie Eikemo[1], Hedda Maurud[1], Siri Leknes[1]; [1]Department of Psychology, University of Oslo

The eyes are the facial feature that receive most visual attention. Eye contact is an important social signal for affiliative motivations such as friendliness, interest, and romantic attraction. The neuropeptide oxytocin is widely known for its role in social attachment and bond formation, and one proposed mechanism of oxytocin is increased attention to the eye region of faces. However, several other neurochemical systems are implicated in human attachment behavior. One of them, the μ-opioid system is proposed to mediate the capacity for affiliative reward in humans. We assessed the role of the human opioid system in a basic social behavior: looking at someone's eyes. In this randomized double blind cross-over study, 30 healthy males received a μ-opioid agonist (morphine 10 mg), a non-selective opioid antagonist (naltrexone 50 mg) or placebo (per-oral) on three separate days. Participants rated attractiveness of faces while their eye movements were recorded. Fixation time and fixation count for selected regions of interest were analyzed using a multiple regression approach (generalized linear mixed model in SPSS). We hypothesized that ingestion of an opioid agonist would increase, whereas an opioid antagonist would decrease, the time spent looking at the eye region. Analysis revealed the expected linear effect of the opioid drug manipulation on both looking time and fixation count for the eye region, such that morphine significantly increased and naltrexone significantly decreased the number of fixations, as well as the time spent fixating on the eyes. By demonstrating that the endogenous opioid system mediates gaze pattens to the socially significant eye region, our results provide causal evidence of the opioid system's role in the basic human social behavior of looking someone in the eyes.

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56.544 **Sex Differences in the Social Evaluation of Faces** Ashley Unger[1](aunger5013@gmail.com), Alexander Todorov[2], Virginia Falvello[2], K. Suzanne Scherf[1]; [1]Psychology, Penn State University, [2]Psychology, Princeton University

People use the structure of the human face to form social impressions about each other, including social status and personality traits. Given that these social dimensions of face processing have direct relevance for motivating social behavior (e.g., selecting potential mates), we evaluated sex differences in sensitivity to the perceptual cues that are used to evaluate faces on these dimensions. We focused on evaluations of dominance,

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which are based on facial cues that signal physical strength and predict social rank and access to potential mates for male faces. We hypothesized that males would be more sensitive than females to detect physical dominance in other male faces. We tested heterosexual young adult males and females in a perceptual sensitivity paradigm to determine the just noticeable difference in dominance between two versions of the same face identity. For each identity, we created 13 morphed versions of the face that included increasingly more perceptual cues to dominance (Todorov et al., 2008). Participants were presented with pairs of faces (original face vs. morphed face) in a staircase procedure and they determined which of the two faces was more dominant. In contrast to our hypothesis, male participants exhibited lower thresholds for detecting dominance in female faces, and female participants were faster to detect dominance in male faces (at the same threshold as males). These findings suggest that heterosexual adults may be relatively biased to detect dominance in opposite sex faces. To confirm this interpretation, we will present additional data in a new sample of adults evaluating sensitivity to dominance in both male and female faces, but also to likability and attractiveness, the judgments of which are not correlated with dominance. These findings will help determine whether the observed sex differences are specific to dominance evaluations or generalize to a broader set of social evaluations about faces.

56.545 **Are first impressions the same for male and female faces?**
Clare Sutherland[1](cs770@york.ac.uk), Julian Oldmeadow[2], Andrew Young[1]; [1]Department of Psychology, University of York, [2]Psychological Science and Statistics, Swinburne University of Technology

Models of first impressions from faces have emphasised two social attribute dimensions in particular: trustworthiness (approach/avoid) and dominance (capability). These face perception models bear a strong resemblance to social psychological models of group/stereotyping perception that describe similar dimensions of warmth and competence. We investigated whether these face and social perception dimensions are equivalent for first impressions of male and female faces. In a first study, we collected ratings of warmth, trustworthiness, competence and dominance (n = 40) for 1000 ambient image face photographs. We found that while trustworthiness and warmth ratings are highly related, dominance and competence ratings are less strongly related, especially for female faces. This can be seen as a stereotyping effect linked to negativity associated with female dominance, or in line with evolutionary models which posit that dominance impressions are especially important for male faces. In a second study, we examined whether male and female participants (n = 24) had similar first impressions from faces as well as establishing that our face gender differences were robust across participants. Ratings from male and female participants were highly correlated, indicating that facial first impressions are highly similar across participant gender, but not face gender.
Acknowledgement: ESRC studentship (first author)

56.546 **The other-race effect of face processing: Upper and lower parts play different roles**
Yu-Hao Sun[1,2](sunyuhao@zstu.edu.cn), Zhe Wang[1], Paul Quinn[3], Xiaoyang Yu[1], Jim Tanaka[4], Olivier Pascalis[5], Kang Lee[2]; [1]Department of Psychology, Zhejiang Sci-Tech University, PR China, [2]Institute of Child Study, University of Toronto, Canada, [3]Department of Psychology, University of Delaware, USA, [4]Department of Psychology, University of Victoria, Canada, [5]Laboratoire de Psychologie et NeuroCognition, Université Pierre-Mendès-France, France

We investigated whether individuals would show differential sensitivity to configural and featural changes in different regions of own- and other-race faces. Using the Face Dimensions Test, we systematically varied the size of key facial features (eyes and mouth) of own-race Chinese faces and other-race Caucasian faces, and the configuration (spacing) between eyes and between eyes and mouth of the two types of faces. The feature size and spacing between features were manipulated on three levels: small, medium, and large. On each trial, when a pair of faces (both Caucasian or both Chinese) was presented side by side, participants were asked to discriminate between them. Results revealed that the ORE is more pronounced when featural and spacing change was in the upper region than in the lower region of the face. Participants performed significantly better for own-race face pairs than other-race face pairs when size and spacing change were in upper region of the faces (i.e., eye size and the distance between two eyes), but not when size and spacing change were in lower region of the faces (i.e., mouth size and the distance between nose and mouth). These findings reveal that information from different regions of the face contributes differentially to the robust difference in recognition between own- and other-race faces.

56.547 **Testing the Effects of Race on the Recognition of Disguised Faces**
Jessie Peissig[1](jpeissig@fullerton.edu), Colleen Dillon[1], Charles Saavedra[1], Cindy Bukach[2]; [1]California State University Fullerton, [2]University of Richmond

In this study we tested three races (Asians, blacks, and Caucasians) to determine whether race had any effect on how people recognize disguised faces. Participants (n=43) initially viewed a set of 12 faces and were asked to make a judgment of the face (i.e., is the person introverted/extroverted). They were then given an intervening irrelevant face task. Finally, participants were asked to identify if any of the faces within a simultaneous lineup had been seen during the initial part of the experiment (old/new task). The lineups were made up of four individuals matched on both race and gender. There were 48 lineups, 24 of which included an "old" face and 24 which did not. In the initial training phase the faces were shown undisguised (six faces, half male/half female, two of each race), or disguised with a wig and glasses (six faces, half male/half female, two of each race). During the final old/new task, all the faces were shown without disguises; thus some faces were changed between disguise and test (disguise removed) and some appeared the same. In addition, the faces shown were either Asian, black, or Caucasian and participants were also Asian, black, or Caucasian. Our results did not indicate an Other Race Effect within this disguise manipulation. Rather, for all three groups of participants, the biggest difference between disguised and undisguised was for Caucasian faces, the second biggest difference was for Asian faces, and smallest difference was for black faces. These findings may indicate that disguised are more disruptive for some races than others, perhaps because the disguises are obscuring the specific perceptual cues that are particularly relevant for individuation within that racial category.
Acknowledgement: California State University Fullerton Incentive Grant

56.548 **Impact of Prejudice on Ethnic Ingroup and Outgroup Mental Representations**
Olivier Paquin[1](paqo01@uqo.ca), Daniel Fiset[1], Geneviève Forest[1], Mélina Jalbert[1], Caroline Blais[1]; [1]Département de psychologie et de psychoéducation, Université du Québec en Outaouais

Dotsch et al. (2008) have shown that ethnic outgroup faces are perceived as less trustworthy and more criminal looking in the prejudiced mind. Since prejudice also involves favoritism towards the ingroup (Brewers, 1999), we hypothesized that not only the mental representations of outgroup faces are negatively biased in prejudiced individuals but also that their mental representations of ingroup individuals are positively biased. To reveal the prototypical representation of African-American (AA) and Caucasian (Ca) faces, we used Reverse Correlation (Mangini & Bierderman, 2004). On each trial, two stimuli (base face + and – visual noise) were presented simultaneously on the screen, and the participant had to decide which one of the two was most typical of each ethnic group (i.e. AA or Ca). Thirty-seven participants underwent 500 trials for both ethnic representations, and completed an Implicit Association Test (IAT) to determine their level of prejudice against AA. Classification images (CI) representing prototypical AA or Ca faces were computed separately for each participant by averaging the noise patterns of the stimuli selected as most representative. Subsequently, twenty independent participants judged the level of trustworthiness, criminality, and successfulness displayed by the CI. For each judge and for each social judgment, a linear regression was performed on the IAT scores and the judge's ratings of the CI. Subsequent t-tests on the regression coefficients showed that the more prejudiced a participant was, the less trustworthy [$t(19)=4.44$, $p<.001$] and potentially successful [$t(19)=4.74$, $p<.001$], and the more criminal looking [$t(19)=-2.38$, $p<.05$] their mental representations of AA were judged. Interestingly, the more prejudiced a participant was, the more trustworthy [$t(19)=-4.02$, $p<.001$] and potentially successful [$t(19)=-4.17$, $p<.001$] their representation of a Ca was judged. These results show that prejudice does not only bias the representation of the ethnic outgroup faces, but also those of the ingroup faces.
Acknowledgement: Social Sciences and Humanities Research Council (SSHRC)

56.549 **The time course of visual information extraction for identifying and categorizing same and other-race faces in Caucasian observers**
Sandra Lafortune[1](lafs37@uqo.ca), Caroline Blais[1], Karolann Robinson[1], Jessica Royer[1], Justin Duncan[1], Jessica Tardif[1], Daniel Fiset[1]; [1]Département de Psychologie, Université du Québec en Outaouais

It has been proposed that the categorization of a face as part of an ethnic group occurs spontaneously, whereas its individuation is effortful (Hugenberg et al., 2010). In this framework, the other-race effect (ORE) arises from a tendency to attend race-specific, as opposed to identity-specific, features. Here, dynamic Bubbles (Vinette et al., 2004) were used to investigate the time course of feature utilization during the identification and categorization of same-race (SR) and other-race (OR) faces. The stimuli consisted of 300ms

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movies displaying a face (8 Caucasian, 8 African-American) in which information was randomly sampled through time. On each trial, the participant (N=8, 9600 trials) had to decide which of the 16 identities was presented. The number of bubbles was adjusted such that on 15% of the trials, race-categorization errors occurred (erroneous identification of a face of the wrong ethnicity). This manipulation allowed us to reveal, using a single task, identity-specific and race-specific information. On average, the participants correctly identified 39.9% of the SR, and 27.4% of the OR, faces, replicating the ORE [t(7)=4.01, p<0.05]. We first computed static classification images (CI) showing race-specific and identity-specific visual information by performing a multiple linear regression on the bubbles' spatial and temporal locations and accuracy at categorizing or identifying faces. Diagnostic identity-specific information was located in the eye region, whereas race-specific information was located on the left nostril and the whiter part of the eyes (Zcrit=3.98, p<0.05). We then constructed dynamic CIs separately for SR and OR faces showing the time course of information utilization for identification and categorization. We correlated each frame of the dynamic CIs with the identity- or race-specific CIs. The results show that for SR faces, identity-specific information is processed earlier and more thoroughly, whereas for OR faces, it is the race-specific information that is treated as such.

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56.550 Judgments of Personality Traits from Real World Face Images Samuel Anthony[1,3](santhony@wjh.harvard.edu), Walter Scheirer[2,3,4], Ken Nakayama[1,3]; [1]Department of Psychology, Harvard University, [2]Department of Molecular and Cell Biology, Harvard University, [3]Center for Brain Science, Harvard University, [4]Department of Computer Science, Harvard University

Oosterhof & Todorov (2008) have shown the surprising reliability of human judgments of personality from faces (traits like trustworthiness and dominance). However, the bulk of this work has relied on in-lab ratings of well-controlled stimuli with a high degree of similarity (including all frontal poses). We used a large web sample (using TestMyBrain.org) for judgments on a large, heterogeneous set of faces that allows us to explore the perception of trustworthiness and dominance in real world contexts, as well as developing a computational framework based on the details of human performance (Anthony et al., 2013). Subjects (N=9899) made pairwise comparisons of faces along three dimensions: dominance, trustworthiness, and age. 30% of the images in a block were sampled from a set of 66 neutral frontal face images previously rated for dominance and trustworthiness by Todorov. 70% were sampled stochastically from 13,971 face images collected from Flickr. These uncontrolled images are maximally variable with respect to pose, expression, lighting, occlusion and makeup. We examined reliability of the ratings via two methods. The ratings of the Todorov faces correlated essentially perfectly with Todorov's prior ratings. On the Flickr set we found (by splitting the dataset and looking at correlations between the two halves) 4422 images (those with more than thirty comparisons per dimension) had highly reliable ratings (average correlations of 0.9 and above). These images comprise our set for analysis and algorithm training. This work confirms that reliable human judgment of personality traits is maintained across a set of maximally variable images, opening the door to explore other determinants of these traits as well as providing data for machine vision applications. For example, we show that trustworthiness and dominance show characteristic relations to perceived age. Also, these images provide a sufficient training/test sample for algorithms to mimic human judgments of these traits.

56.551 On the Modulation of Social Inference from Faces across Viewing Distance Daniel Gill[1](daniel.gill@glasgow.ac.uk), Rachael Jack[1], Philippe Schyns[1]; [1]Institute of Neuroscience and Psychology, University of Glasgow

Inference of social traits from faces is a prominent factor in everyday social interactions. As such it is supposed to be susceptible to evolutionary pressures affecting detection sensitivities of specific social context. Previous studies have shown in a multi trait rating task (Oosterhof & Todorov, 2008), that the valence dimension (first principal component) has been found to capture most of the variance (68%) whereas the second principle component, well aligned with dominance, was found to capture only 18% of the variance. It has been suggested that the latter structure expresses the priority of evaluation of intention over evaluation of dominance in a chance encounter. Here we address the issue of the modulation of social impression from faces across varying viewing distance. In a four social trait rating task (trustworthiness, dominance, attractiveness and aggressiveness) and simulation of varying viewing distances ranging from 2.5 to 80m we addressed this question by (i) evaluating the composition of diagnostic information across that viewing distance by classification images (ii) reconstructing the structure of the viewing-distance-dependent social space by measuring its principal components. The results show a varying composition of diagnostic information across viewing distance. Whilst in long viewing distance face and hair color (e.g. face redness) serve as major diagnostic features, in short viewing distance inner facial features (such as eyebrows) become diagnostic as well. In addition we show that at a long viewing distance loading on the first principal component of dominance is high and that of trustworthiness is low. When viewing distance is becoming shorter the loading on the first principal component of dominance becomes lower and that of trustworthiness becomes higher. The latter results suggest a viewing distance dependent tuning of social perception: priority of evaluation of counterpart's capacity in far viewing distance and priority of intentions in short distance.

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56.552 Effects of bowing on perception of attractiveness Jun Kawahara[1](jkawa@lets.chukyo-u.ac.jp), Takayuki Osugi[2]; [1]Chukyo University, [2]University of Tokyo

Greeting is an act of human communication between individuals coming into contact with each other. The present study focused on bowing as a greeting behavior and examined its modulating effects on perception of attractiveness. We found slight tilting motion of portraits, simulating bowing enhanced perceived attractiveness. In each trial, a portrait digitized from university yearbooks was presented on a computer screen. The portrait could gently tilt toward participants to simulate a greeting bow (25 degree angle). Participants evaluated the subjective attractiveness of the face using a visual analog scale (0-100). The mean attractiveness judgment of the bowing portrait was significantly higher than ratings of the portrait bending backwards or remaining upright, as control conditions. Additional control experiments revealed that alternative effects relying on apparent spatial proximity, physical characteristics, and relative social standing could not solely explain the effect of bowing, and indicated that the effect was specific to objects perceived as faces. Specifically, sliding the bottom side of the portrait toward or away from participants did not affect the attractiveness rating. No difference in rating scores was found between the static (bending toward or backward and upright face) images. The bowing motion did not improve the ratings of inverted faces and non-face meaningless drawings. The bowing motion did enhance the attractiveness of pareidolia objects, such as a picture of an electrical outlet. Finally, observers' in-return bowing behavior did not reduce the bowing effect, indicating that the effect is not attributable to relative enhancement of social standing of the observers who did not bow in the original experiment. These results suggest that a tilting motion of portraits of faces (or face-like objects) mimicking bowing enhances physical attractiveness, at least as measured in a culture familiar with greeting by bowing.

56.553 Hot or Not? Perceived Attractiveness Activates Reward Processes Within Medial-Frontal Cortex Olav Krigolson[1](krigolson@dal.ca), Scott Whitaker[1], Laura MacKenzie[1], Cameron Hassall[1]; [1]Department of Psychology and Neuroscience, Dalhousie University

Utilitarian theory posits that we are driven by an inherent desire to maximize reward. Not to be superficial - but given this logic when one views an attractive face the face should be desired and processed as a reward whereas when one views an unattractive face it should be processed as a punishment. Indeed, research using functional magnetic resonance imaging supports this hypothesis – in a seminal study Aharon and colleagues (2001) showed that the viewing of attractive faces activated neural reward circuitry relative to the viewing of unattractive faces. Here, we sought to provide electroencephalographic (EEG) support for this hypothesis. Specifically, we recorded electroencephalographic data while participants viewed and rated faces on a Likert scale for attractiveness. Following data collection we used the participants' ratings to code faces as either being attractive or unattractive. Based on these codings, an analysis of our electroencephalographic data revealed that a contrast of "attractive" and "unattractive" faces revealed an event-related brain potential component with a timing and scalp topography consistent with the feedback error-related negativity (fERN) – a component previously shown to be sensitive to reward feedback. Further, localization of the fERN we observed revealed a source within the anterior cingulate cortex – a result also consistent with previous accounts of the fERN. Importantly, our results provide further support for the hypothesis that perceived attractiveness activates reward-processing circuitry within the medial-frontal cortex.

Acknowledgement: NSERC

56.554 **A Perceptual Space for Describing Human Bodies** Matthew Q. Hill[1](mattqhill@gmail.com), Carina A. Hahn[1], Alice J. O'Toole[1]; [1]The University of Texas at Dallas

Humans regularly describe bodies using global and local feature terms (e.g., pear-shaped, fit, broad shoulders). Remarkably little is known about how these features map onto complex body shapes and how bodies compare perceptually to one another. Here, we "reverse engineered" a human body space from participants' ratings of male and female bodies. Participants (n = 31) rated 60 male and 165 female bodies using 27 common descriptor terms that captured variations in global shape (e.g., rectangular, curvy), local features (e.g., short torso, long legs), physical health (e.g., fit, muscular), and gender-related attributes (e.g., masculine). The rating choices for each descriptor were: "1: applies perfectly; 2: applies somewhat; 3: does not apply". Ratings were compiled across participants and submitted to a correspondence analysis—a multivariate technique that placed the bodies and feature descriptor terms in a common space. We generated separate multidimensional spaces for female and male bodies. For both spaces, axis 1 captured weight variation, axis 2 captured height variation, and axis 3 described sex-specific global shape variations. The sex-specific shape variations in the female body space contrasted "curvy" and "pear-shaped" with "skinny" and "lean"; for males, it contrasted "muscular" and "built" with "skinny" and "small." An additional common axis (4th for males, 5th for females) captured variation in the ratio of torso and leg length, contrasting bodies having short torsos and long legs with bodies having long torsos and short legs. Combined, the described axes explained 62% of the variance for the male space and 59% for the female space. These spaces offer a first look at the perceptual structure of human body variability and give insight into how individual bodies align with the labels used to describe them. The results suggest that relatively stable perceptual representations of bodies can be reverse engineered from linguistic labels.

56.555 **Pupil constriction during visual preference decision** Hsin-I Liao[1](liao.hsini@lab.ntt.co.jp), Shinsuke Shimojo[2,3], Makio Kashino[1,3]; [1]NTT Communication Science Laboratories, NTT Corporation, [2]Division of Biology, California Institute of Technology, [3]Japanese Science Technology, Core Research for Evolutional Science & Technology (JST, CREST)

Eyes reveal our internal cognitive status. In our previous studies, we found that gaze is biased towards the preferred image ("the gaze cascade effect", Shimojo et al., 2003), and this gaze bias has stronger accumulation for a familiarity preference than novelty preference (Liao & Shimojo, 2012). It also has been known that pupil dilates when we see someone attractive. Taken together, we aim to examine whether pupil dilation can be also a physiological marker for preference decision, and whether it reflects familiarity and novelty preference differently. A pair of a repeatedly presented image and a novel image was presented side-by-side on the screen. Three categories of images (faces, natural scenes, and geometric figures) were used and the paired images were always in the same category. Participants performed a two-alternative-force-choice (2AFC) preference task while their pupillary response was recorded. The images were presented with unlimited time until participants made their decision by pressing a button. Results showed that, to our surprise, instead of dilation, pupil constricts during the preference decision. Similar amounts of pupil constriction were observed for familiarity preference and novel preference. The effect of preference decision on pupil constriction was consistently observed in all the three stimulus categories we tested. Lower-level artifacts, such as average luminance changes or environmental lightings, are unlikely according to our stimulus parameters and pilot observations. The counter-intuitive result that it is pupil constriction rather than dilation observed, is contradictive to predictions related to attractiveness or attention. Further studies are required to understand how mental states involving preference decision correspond to pupil response and its underlying mechanisms.

56.556 **The influence of pupil alignment on the address of spectators to portraits painted by Edouard Manet.** Nick Donnelly[1](nd5@soton.ac.uk), Beth Harland[2], Simon Liversedge[1]; [1]Psychology, University of Southampton, [2]Institute of Contemporary Art, University of Lancaster

Art theoretical accounts of the work of Edouard Manet describe it as challenging traditional forms of address made by paintings to spectators. His radical method conflates absorptive and theatrical modes of address, placing the spectator in an uncertain position in relation to the picture. His paintings often simultaneously acknowledge the viewer (theatrical mode), and offer little acknowledgement of the spectator's presence, thereby retaining aspects of an absorptive 'anti-theatrical' mode. Recently, we investigated the double relation to the spectator in Manet's seminal A Bar at the Folies Bergere (Harland et al., Leonardo, 2013). Here we examine pupil alignment as a mechanism for manipulating spectator address in his portrait paintings. Three art experts independently classified Manet's entire portfolio of (70) oil portraits that allowed judgment of perceived alignment or misalignment of pupils to a single point in space. Judgments were made separately for horizontal and vertical axes. We counted high confidence in judgments of alignment and misalignment when agreement was perfect across experts. 64% of portraits were classified with high confidence as having misaligned pupils on either horizontal or vertical axes. Of the portraits with misaligned pupils, 82% were misaligned on the horizontal axis. The significance of the relative difference in frequencies of misaligned and aligned pupils across horizontal and vertical axes was confirmed using a 2x2 Fisher Exact test ($p<0.008$). Our analyses demonstrate that Manet frequently painted portraits with misaligned pupils, and that this misalignment was heavily weighted to the horizontal axis (which may reflect the relative incidence of exo/esotropia versus hypo/hyperphoria in the general population). These findings are consistent with the suggestion that Manet introduced high levels of ambiguity in the sitter's gaze to complicate the usually inherent theatricality of the portrait form, and to introduce an ambiguous double address, at once absorptive and acknowledging.

Object recognition: Features and parts

Tuesday, May 20, 2:45 - 6:45 pm

Poster Session, Pavilion

56.557 **The role of spatial frequencies in expert object recognition** Simen Hagen[1](shagen@uvic.ca), Quoc C. Vuong[2], Lisa S. Scott[3], Tim Curran[4], James Tanaka[1]; [1]University of Victoria, [2]Newcastle University, [3]University of Massachusetts Amherst, [4]University of Colorado Boulder

Objects are typically recognized at the basic level (e.g., bird) in which the external contour shape of the object is important for recognition. Experts, on the other hand, typically recognize objects at the subordinate level (e.g., sparrow), which seem to depend more on internal features of objects. Here we investigated whether bird experts rely on internal object features to facilitate fast and accurate subordinate-level recognition of objects in their domain of expertise. We filtered bird images over a range of spatial frequencies corresponding to 2-4 cycles per image (cpi), 4-8 cpi, 8-16 cpi, 16-32 cpi, and 32-64 cpi. This manipulation preserved the external shape of the object while systematically degrading its internal feature information. In Experiment 1, bird experts and novices categorized common birds at the subordinate, family-level (e.g., robin, sparrow, cardinal). The main finding was that experts were faster and more accurate than novices. Moreover, experts were fastest with images filtered between 8 cpi and 32 cpi in which external and internal information were both preserved. In Experiment 2, experts categorized birds at the subordinate, species level (e.g., Wilson's warbler, Tennessee warbler), in which external shape is less diagnostic and internal features are more important to identification. For species-level categorizations, experts were faster at recognizing birds filtered between 4 cpi and 32 cpi relative to images filtered at 2-4 cpi. Response time distribution analyses revealed that only images filtered at 8-16 cpi led to a reaction time advantage in the fastest trials. In summary, bird experts form elaborate object representations that include information about the internal features of birds allowing them to make fast and accurate subordinate-level recognition for objects in their domain of expertise.

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56.558 **Intrinsic versus contextual features in object recognition** Derrick Schlangen[1](dschlang@fau.edu), Elan Barenholtz[1]; [1]Florida Atlantic University

Previous experiments using degraded target objects have shown that recognition is facilitated by contextual information (Bar & Aminoff, 1996; Barenholtz, In Press). Yet, it is not known how effective this contextual information is relative to other sources of information, such as an object's intrinsic visual features. To address this, we performed four experiments using rendered scenes with novel objects, in which the features and locations of the objects could be experimentally manipulated. In all four experiments, participants first performed a visual search task, searching for uniquely shaped target objects within the scene. The objects' colors and location within the context were statistically manipulated during the search phase. We then tested participants' tendency to use their knowledge of the location/color information for the purposes of recognition when the object's image was degraded due to blurring, eliminating the shape information. In Experiment 1, we found that, in the absence of any diagnostic intrinsic features, participants identified objects based purely on their locations within the scene. In Experiment

2, we found that participants combined an intrinsic feature, color, with contextual location in order to uniquely specify an object. In Experiment 3, we found that when an object's color and location information were in conflict, participants identified the object using both sources of information equally. Finally, Experiment 4 found that participants used whichever source of information was more statistically reliable—either color or location— in order to identify the target object; however reliable location was given higher priority than reliable color. Overall, these experiments show that the context of objects may be a potent source for object identification, playing as important a role as intrinsic object features under some conditions.

56.559 **Object interpretation: extending and validating object recognition** Guy Ben-Yosef[1](Guy.Ben-Yosef@weizmann.ac.il), Liav Assif[1], Danny Harari[1,2], Ethan Fetaya[1], Shimon Ullman[1]; [1]Department of Computer Science and Applied Mathematics, Weizmann Institute of Science, [2]Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology

Unlike current computational models for object recognition, when humans recognize an object-image, they obtain not only the identity of the object, but also the identity and locations of a set of internal object features. We describe a computational model that combines object recognition with a process that obtains a full internal interpretation of the object structure. Our model is based on both psychophysical and computational considerations and testing. We used for the training and testing a set of closely similar image pairs, as judged by a trained classifier, in which one member of the pair contains a class example, and the other contains a non-class image. The differences between these images were used to infer the class-structures that observers identify in class images. The model includes a set of primitive features and certain relations defined over them. The primitives are divided into three types, 2-D(regions), 1-D(contours), and 0-D(points). The relations include unary (properties), binary, and more global relations between three or more primitives. Examples include local intensity extrema, parallelism and continuity between two contours, containment of point feature in region, and configurations of several contours, regions or points. The extraction of these relations employs both bottom-up and top-down mechanisms, inspired by biological vision findings, and implemented by state-of-art learning and computer vision tools. To interpret the internal structure of a novel image, our scheme first extracts a set of image measurements for candidate primitives of type points, contours, and regions, and then assigns candidates to primitives by their comparability with the set of learned relations. This assignment is the final interpretation of the object structure. We applied the scheme to object-images that are difficult to recognize for current models, to test the capacity of the interpretation scheme to validate and improve recognition. We show experimental results on several challenging categories.

Acknowledgement: ERC Digital Baby ERC grant

56.560 **Statistics of three-dimensional objects and object representation** Jin Qi[1,2](jqichina@hotmail.com), Zhiyong Yang[1,3,4]; [1]Brain and Behavior Discovery Institute, Georgia Regents University, [2]Electrical Engineering Department, University of Electronic Science and Technology of China, [3]James and Jean Culver Vision Discovery Institute, Georgia Regents University, [4]Department of Ophthalmology, Georgia Regents University

Object encoding has been the focus of computational modeling and neuro-physiological studies in the last 30 years. Neuro-physiological studies have revealed much information about the processing of object recognition from V1 to V2, V4, and to the IT area, but computational modeling has not incorporated this information. We propose a scheme of object representation that incorporates a number of facts about the neural codes of objects. In this scheme, an object is encoded by a hierarchical model that includes three probability distributions (PDs), i.e., PD of object parts and geometry, PD of natural object structures (NOS), and PD of spatial arrangements of NOS. Here, NOS are topology-conserving, multi-view, multi-scale, spatial concatenations of 2D and 3D object features (depth, surface orientation, and surface curvature). We took five steps to compile NOS: 1), sample a large number of patches of natural objects using a hexagonal configuration; 2) perform independent component analysis on the circular patches and obtain independent components (ICs); 3) fit Gabor functions to the ICs and classify the ICs into 16 orientations and a set of clusters for each orientation; 4), project the circular patches to the clusters of ICs and compute the features of the circular patches; and 5), partition the space of feature vectors into a set of NOS. Using this procedure, we obtained a large number of NOS from a dataset of 200 small natural objects acquired by a laser range scanner and a digital camera. These NOS provide a classification of natural object patches and include all concatenations of 2D and 3D object features. Since NOS include 2D and 3D features, this model unifies structural, 3D-based and appearance-based approaches to object recognition. We tested this model of 3D object recognition and found that the performance comparable to or better than current models of 3D object recognition.

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56.561 **Greater Sensitivity to Nonaccidental than Metric Shape Properties in Preschool Children** Sarah B. Herald[1](bergsma@usc.edu), Manan P. Shah[1], Ori Amir[2], Irving Biederman[1,2], Toby Mintz[1,2]; [1]Neuroscience Program, University of Southern California, [2]Psychology Department, University of Southern California

Nonaccidental properties (NAPs) are image properties that are invariant over orientation in depth and allow facile recognition of objects at varied orientations. NAPs are distinguished from metric properties (MPs) that generally vary continuously with changes in orientation in depth. While a number of studies have demonstrated greater sensitivity to NAPs in human adults, pigeons, and macaque IT cells, the few studies that investigated sensitivities in preschool children failed to find significantly greater sensitivity to NAPs. However, these studies did not provide an adequate principled measure of the physical image differences for the MP and NAP variations. We assessed sensitivity to NAP vs. MP differences in a match-to-sample experiment in which 14 preschool children were instructed to choose which of the two lower shapes was different from the top sample shape in a triangular array of the three shapes. Importantly, we scaled the shape differences so that MP and NAP differences were roughly equal, using the Gabor Jet model of V1 similarity (Lades et al., 1993). That model provides almost perfect predictability of psychophysical similarity in discriminating metric shape variations (Yue et al., 2012). Mean reaction times (RTs) for every child were shorter when the target shape differed from the sample in a NAP than an MP. The results suggest that preschoolers, like adults, are more sensitive to NAPs than MPs. This could explain their ability to rapidly learn new objects without having to observe them from every possible orientation.

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56.562 **Object gist features capture the structure of neural responses to objects** Talia Konkle[1,2](tkonkle@gmail.com), Alfonso Caramazza[1,2]; [1]Psychology Department, Harvard University, [2]Center for Mind/Brain Sciences, University of Trento

There is systematic structure in the neural responses to visually presented objects across the ventral and dorsal streams. What are the key properties of objects that drive these responses? To explore a broad space of possibilities, we considered properties that reflect how we interact with objects (action), where they are found (context), what they are for (function), how big they are (real-world size), and what they look like (object gist). Estimates for these feature spaces were obtained for a set of 200 inanimate objects, using either behavioral rating experiments or image-based measures that capture global shape structure (Oliva & Torralba, 2001). Using fMRI, we obtained neural response patterns for 72 of these items in 11 participants. To analyze the structure in the neural responses, we used a feature-modeling approach (Mitchell et al., 2008; Huth et al., 2012), which fits a tuning model for each voxel along a set of feature dimensions (e.g. object gist features, action features). We found that a large proportion of posterior visual cortex was well-fit by the object gist model (mean r2=0.54). In a leave-two-out validation procedure, this object gist encoding model could accurately classify between two new object patterns with near perfect accuracy (96% SEM=1%). The feature spaces of action, context, function, and real-world size all were also able to classify objects but with lower overall accuracy (61%-68%). These models fit best along more anterior regions of object-responsive cortex, extending along PHC, TOS, and IPS. Thus, while these abstract properties of objects capture some of the structure in neural object responses, the results indicate that most of visually-responsive object cortex represents global form properties, i.e. object gist.

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56.563 **Systematic eye movements during recognition of emerging images** Barbara Nordhjem[1](b.j.t.nordhjem@umcg.nl), Constanza I. Kurman Petrozzelli[1], Nicolás Gravel[1], Remco Renken[2], Frans W. Cornelissen[1]; [1]Laboratory of Experimental Ophthalmology, University of Groningen, University Medical Center Groningen, [2]BCN Neuroimaging Center, University of Groningen, University Medical Center Groningen

Human observers are able to group elements and fragments into whole shapes. This is the underlying concept of emergence. Yet, it is still unclear how information is sampled when emergence occurs. Usually, the process of object recognition is too fast to trace, but by using images with emerging properties we were able to study eye movements before, during and after the moment of recognition. Stimuli consisted of computer-generated emerging images (Mitra, Chu, Lee, and Wolf (2009)) resembling the famous Dalmatian against a dappled background. Forty observers each viewed fifteen emerging images while their eye movements were tracked. They indicated the moment of recognition by pressing a key. Results show that three phases could be distinguished in the eye movement patterns prior to and after recognition. In the first phase, initial fixation durations were relatively short and eye movements were distributed over the entire stimulus. In the second phase, which started approximately one second before recognition, there was a transition towards longer fixations targeted at the edges of the object. In the third phase, which started following recognition, fixations again became shorter and somewhat more distributed. Within the second phase just prior to recognition, additional viewing patterns could be identified: fixations were first made just outside the edges of the object, then there were more fixations inside the object and finally, fixations were made right on the edges of the emerging object. Our results show that the characteristics of eye movements are closely associated with the conscious experience of emergence. The distinct systematic patterns in the eye movements suggest that the recognition process can be divided into perceptually relevant temporal phases.

56.564 The temporal dynamics of 3D object recognition for mono- and stereo visual displays: An ERP study

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There is now a growing body of evidence that the visual system can, under some conditions, make ultra-rapid image classification judgements within around 100-150ms of stimulus onset (e.g., Thorpe et al., 1996, Nature). However, there have been relatively few studies investigating the temporal dynamics of three-dimensional (3D) object recognition, and shape recovery during visual perception – and most previous work has been restricted to studies based on two-dimensional (2D) stimulus displays ignoring potential effects of stereo disparity on the time course of shape processing. We investigated this issue using high-density (256-channel) EEG to record the temporal dynamics of object recognition to novel, multi-part, objects under conditions of mono- and stereo visual presentation. On each trial participants made shape equivalence ('Same'/'Different') judgements to two briefly presented images of novel objects. There were two blocks each of mono- and stereo trials. There were no differences between conditions on the P1 component, but differences between 2D and 3D stimuli arose at the N1, exhibiting a greater negativity over posterior occipito-temporal leads and a stronger positivity over anterior electrodes at around 170ms for 3D views. The same vs. different shape contrast produced ERP modulations during the N2, between 250ms-330ms. A topographic segmentation analysis suggested that 2D and 3D views differed in the intensity of the N1 map, while same vs. different shape stimuli produced distinct N2 map configurations that emerged independently of depth.These results show that stereo disparity modulates the time course of recognition early in the course of visual processing by enhancing the response at around 170ms. The increase in N1 could reflect the accumulation of visual information that allows shape integration to occur more efficiently during the N2 without necessarily modulating the timing of shape recognition per se.

56.565 Task-Dependent Reliance on Image Fragments in Humans

W. Drew Bromfield[1](wabromfi@umail.iu.edu), Thomas James[1]; [1]Indiana University, Bloomington

Previous work has shown that image fragments informative for one task are not always the most informative for a different task with same set of stimuli and that neural responses in humans are sensitive to differences in task-dependent information (Nestor, Vettel, & Tarr, 2008). Thus, humans may actively rely on different aspects -- possibly visual fragments or features -- of a stimulus depending on the current task. We tested this possibility using an aperture-viewing paradigm (James, Bushmakin, et al. 2011) and a 2 interval same-different task. We used two categories of stimuli: female faces and cars. There were 4 individuals in each category, with two distinct instances per individual. Different instances for faces were expressions (happy, neutral), and for cars were viewpoints. Subjects were first presented with an image behind an occluder and explored the image through an aperture that was moved continuously by the subject via the mouse. A second image was then presented and a response was made to indicate whether or not it was 'the same' as the first image. Task condition dictated the criteria for a successful same response. For categorization, two images were the 'same' if they were from the same category (cars, faces) regardless of which individual or which instance. For individuation, two images were the 'same' if they depicted the same individual, regardless of which instance. Heat maps of viewing time were thresholded to select fragments that subjects relied on for success. Both face and car fragments revealed task-dependent differences regarding which regions subjects relied on. However, face fragments exhibited significantly more overlap across individuation and categorization tasks than did car fragments. These findings suggest that while humans do rely on different regions of a stimulus depending on task, they may employ a more consistent viewing strategy across situations for faces than cars.

56.566 Evidence for Feature Integration in the Fusiform Face Area

Maxim Bushmakin[1,2](mbushmak@indiana.edu), Thomas James[1,2]; [1]Department of Psychological and Brain Sciences, Indiana University, [2]Cognitive Science Program, Indiana University

There is a considerable amount of evidence that different kinds of objects are processed differently by the visual system and brain, but there is a need for more mechanistic explanations for those effects. Specifically, there is a long-standing debate whether the so-called Fusiform Face Area (FFA) is responsible for only face perception or is also involved in other non-face specific cognitive processes (Kanwisher et. al, 1997; Gauthier et. al, 2000). Here, we demonstrate that the FFA is preferentially recruited with non-face objects, but only when participants need to process and integrate multiple, spatially-separated features at the same time. Specifically, I will report on an fMRI study examining face and object perception where participants relied on single features: diagnostic "top" or "bottom" features; or relied on multiple features: conjunction of both "top" and "bottom" features. The main finding was that BOLD signal change was greater in the FFA for conditions with feature conjunctions than with single diagnostic features. We conclude that activation in the FFA is driven in part by the need to integrate object features and suggest that the need to integrate facial features may explain its consistent recruitment with face stimuli. This work has a potential to bring together disparate accounts of face and object perception under a more cohesive and unified framework.

56.567 Dorsal Stream Contribution to Perceiving the Structure of Objects

Valentinos Zachariou[1](zachariouv@mail.nih.gov), Nikas V. Christine[1], Leslie G. Ungerleider[1]; [1]Laboratory of Brain & Cognition, NIMH, NIH

Growing evidence suggests that the functional specialization of the two cortical visual pathways may not be as distinct as originally proposed (Konen & Kastner, 2008; Kravitz, Kriegeskorte & Baker, 2010). Specifically, mechanisms that process the spatial position of objects may also contribute to some aspects of shape perception (Zachariou et al, 2013). This common resource could arise because changes in an object's shape alter location as well, but with respect to the object's parts rather than with respect to other objects. By such an account, perceiving the structure (i.e. shape) of an object, defined as the spatial arrangement of the parts that constitute the object, requires the analysis of location and, hence, dorsal stream processing. Here, we explore this hypothesis in healthy human volunteers who performed a shape-change detection task on two object categories (faces and chairs) while undergoing functional magnetic resonance imaging (fMRI). In each category, two exemplars presented simultaneously on a screen could differ in terms of the shape of their constituent parts (featural differences) or the spatial configuration of their parts (configural differences). For both the face and chair categories, configural differences led to significantly stronger activation within the dorsal visual pathway compared to featural differences. Additionally, the magnitude of this activation correlated with behavioral performance. The dorsal visual pathway was a-priori localized using an independent localizer task. This dorsal activation profile in response to configural differences is particularly noteworthy given that: 1) the visual input was identical for the featural and configural difference stimuli of each category; and 2) the tasks were matched for difficulty. We conclude that the dorsal visual pathway processes the spatial arrangement of elements that constitute the structure of objects and, through this mechanism, contributes to shape perception.

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56.568 Development of Sensitivity to 2D and 3D Information: Infants' Haptic Exploration of Pictures, Objects and Surfaces

Hope Rainey[1](hrainey@haverford.edu), Sarah Shuwairi[1]; [1]Haverford College

Previous research demonstrated that young infants can differentiate between depicted and real objects, and studies have shown that infants use a variety of similar types of manual gestures to examine such displays (DeLoache et al., 1999; Shuwairi et al., 2010; Yonas et al., 2005). Infants generally respond with exploratory actions that tend to include manual gestures appropriate for display type, i.e., grasping for real 3D objects and tapping, scratching and rubbing for depicted ones. Still, questions remain about the nature of infants' conceptual understanding of depicted versus real objects. Here, we carried out a more fine-grained assessment of both the qualitative types of actions (e.g., grasping, tapping, rubbing, etc.) as well as the amount of continuous exploration toward each display type as a measure of persistence. Infants were presented with a real object (i.e., colorful, plastic kitten toy), a color photograph of that object, and a non-object pictorial control stimulus (i.e., light and dark gray patches). We evaluated the types of manual actions, frequency count of actions, and hand height of the initial reach to each of the displays. Infants responded appropriately, albeit slightly differently, to 2D and 3D stimuli – they initiated more grasping to the real object relative to the picture (p <.05), and engaged in a greater number of successive actions overall toward the depicted object relative to the toy and pictorial control (p <.05). Infants clearly do not treat all surfaces and displays alike, they use appropriate types of actions and more persistent exploratory activity overall. This suggests that infants are trying to interpret depth information in the displays as well as understand the nature of pictures and how they differ from actual 3D objects.

56.569 **Effects of delay and distractors in temporal search on clips of fire** Fintan Nagle[1,2](fintan.nagle.10@ucl.ac.uk), Alan Johnston[1,2], Peter McOwan[2,3]; [1]Cognitive, Perceptual and Brain Sciences, University College London, [2]CoMPLEX, University College London, [3]Queen Mary, University of London

Fire has been a ubiquitous natural visual stimulus throughout evolution. The swiftly-changing colour and luminance gradients, and the variety of shapes poses a challenge for dynamic form encoding. Here, we investigated human capacity for dynamic form encoding and recognition, testing the effect of delay and padding on temporal search for dynamic targets within fire clips. In Experiment 1 we used a delayed-match-to-sample task with clips drawn from video of a hearth fire. Subjects viewed a 1-second sample clip followed by a longer test clip, then judged whether the sample was in the test (yes/no). In Experiment 1, we varied the delay between sample and test (1,5,10,15 seconds), and clip orientation (upright, inverted). Performance decreased linearly with time from 67% correct (delay=1 second) to 58% correct (delay=15 seconds) ($p<0.05$, paired-samples t-test). Performance was not significantly different for inverted clips, showing a drop from 67% to 66% (p=0.3, paired-samples t-test). In Experiment 2 we adjusted the temporal position of the 1-second sample in the test clip (test-sample delay 1 second). The sample was preceded by a clip of length x and followed by a clip of length y. We varied x and y independently across {0.25, 0.75, 1.25, 2.25} seconds. The test clip thus lasted x+s+y seconds, whether the sample was present or not. Increasing the length of the post-stimulus padding from 0.25 s to 2.25 s caused a large drop in mean accuracy (from 75% to 52%, averaged across all pre-padding lengths; p=0.0073 by paired-sample t-test). We conclude that detection of target clips of fire degrades linearly with sample-test delay, but is not substantially degraded by inversion (Experiment 1). Furthermore, distractors cause error even when presented after the sample (Experiment 2), showing that dynamic samples of fire are not easily individuated.

56.570 **Object location biases shape and color judgments** Colin Kupitz[1,2](kupitzc@gmail.com), Carina Thiemann[1,2], Julie Golomb[1,2]; [1]Department of Psychology, The Ohio State University, [2]Center for Cognitive and Brain Sciences, The Ohio State University

In our everyday lives, we must coherently bind the features and identities of objects with their spatial locations. We previously showed that location information biases object identity judgments: when two objects share the same location, subjects are more likely to judge them as the same shape (Golomb & Kupitz, VSS 2013). This spatial "congruency bias" is automatic, insuppressible, and unidirectional (object shape does not influence location judgments). Here we examined: (1) if location is truly unique in driving this bias, and (2) how the binding process is influenced by the manipulation of multiple object dimensions. Subjects saw two sequentially presented novel "objects" in the periphery and were instructed to make a same/different comparison of either the objects' shape or color (blocked tasks). Importantly, the objects were independently manipulated along three dimensions: shape, color, and location. Replicating our previous results, when the objects shared a location, subjects reported significantly more "same identity" responses in the shape task. Signal detection theory analyses confirmed the bias, with increases in both hits and false alarms when location was the same. Additionally, we observed a similar location bias in the color task. Interestingly, this bias was unique to location: color did not bias shape judgments, nor did shape bias color judgments. Irrelevant shape and color information did influence how quickly subjects responded (priming), but object location was the only irrelevant dimension that actually biased the responses. Together, these findings provide further evidence for a special role of location in object perception, suggesting that object location is uniquely and automatically encoded – and bound – during object recognition. Preliminary fMRI investigations suggest that the lateral occipital complex (LOC), parietal cortex, and medial temporal lobe may reflect neural substrates of this spatial congruency bias.

56.571 **Feature binding reveals the limit of unconscious visual processing** Zhicheng Lin[1](zhichenglin@gmail.com), Scott Murray[1]; [1]Department of Psychology, University of Washington

The respective role of unconscious and conscious visual processing is a major unresolved question. Some argue that unconscious processing is limited to only simple features and objects such as shape and color, whereas others claim that unconscious processing fully parallels conscious processing. Intermediate between these two extremes, the unconscious binding hypothesis proposes that feature information can be extracted and integrated across space and time without awareness. But just what kinds of information can be integrated? To address this question, we introduce a paradigm that combines metacontrast masking and a go–nogo task. Specifically, we create two types of target objects that can be either visible or invisible: when visible, one is associated with go (i.e., press a button when it appears, referred to as go-associated), the other with nogo (i.e., withhold response when it appears, referred to as nogo-associated); when invisible, both are go trials. The crucial question concerns the invisible target: do participants respond more slowly when it is nogo-associated than when it is go-associated, even though the two could not be consciously differentiated and both are go trials? If so, this would indicate unconscious visual processes that can distinguish the go-associated and nogo-associated targets. Using this logic, we report two main findings. First, shape relations (i.e., whether two objects are the same or different) can be processed without awareness, demonstrating unconscious processing of an abstract same–different concept. This finding suggests that integrating information from a single feature (i.e., shape) across objects is not a signature of conscious awareness. Second, feature binding of shape and color within a single object, however, requires a high degree of conscious awareness, even when shape information is unconsciously represented and color information is consciously accessible. This finding points to feature binding as a signature of conscious awareness.

Object recognition: Mechanisms and models

Tuesday, May 20, 2:45 - 6:45 pm
Poster Session, Pavilion

56.572 **Real-time fMRI search for the visual components of object perception** Daniel Leeds[1,2](dleeds@fordham.edu), John Pyles[2,3], Michael Tarr[2,3]; [1]Department of Computer and Information Science, Fordham University, [2]Center for the Neural Basis of Cognition, Carnegie Mellon University, [3]Department of Psychology, Carnegie Mellon University

The nature of visual properties used for object perception in mid- and high-level vision areas of the brain is poorly understood. Past studies have employed simplistic stimuli limited in the visual details representative of real objects. Unfortunately, pursuit of more complex stimuli and properties requires searching through a wide, unknown space of models and images. The difficulty of this pursuit is exacerbated in neuroimaging by the limited number of samples that can be collected for a given human subject over an experiment. To more rapidly identify complex visual features underlying cortical object perception, we developed and tested a novel method in which visual stimuli are selected in real-time based on BOLD responses to recently shown stimuli. A variation of the simplex method (Cardoso, 1996) controlled continuous stimulus selection within a real-time search through visual image space designed to maximize neural responses across a pre-determined 1 cm3 brain region within ventral cortex. This method was applied using two different stimulus sets: photographs of real-world objects and 3D synthetic "Fribble" objects (Williams 2000). To assess the value of this search method for the understanding cortical object encoding, we examined both the behavior of the method itself and the complex visual properties the method identified as highly activating the selected brain regions within the ventral visual pathway. While further technical and biological challenges remain, our results demonstrated convergence for complex visual properties in the majority of our subjects for a subset of the searches we conducted. More specifically, we were able to identify ventral regions selective for both holistic and component object shapes and for a variety of surface properties, providing evidence that these methods may yield more precise measures of selectivity within the broad classes of visual features associated with cortical object representation (Hung 2012, Tanaka 2003, Vogels 1999).

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56.573 **Neural coding of point-light dynamic objects** John A. Pyles[1,2](jpyles@cmu.edu), Michael J. Tarr[1,2]; [1]Center for the Neural Basis of Cognition, Carnegie Mellon University , [2]Department of Psychology, Carnegie Mellon University

We investigated the role of form information in the neural representation of dynamic objects. Previously, we demonstrated that a large area of higher-level visual cortex (including LOC and hMT+) is recruited during the perception of dynamic objects (Pyles & Tarr, 2013). Moreover, multi-voxel pattern analysis (MVPA) revealed that many regions within higher-level and retinotopic visual cortex encode information about dynamic objects that is invariant across changes in viewpoint, articulation, and size. Our present work extends these findings by investigating the role of form information in the coding of dynamic objects. In two fMRI sessions subjects passively viewed short animations of novel, articulating, dynamic objects: in one session the form of the objects was clearly visible, in another form information was reduced using point-light animations in which only the object's joints were visible. In both conditions subjects saw 80 different example animations (once each) of three dynamic objects which varied across viewpoint, size, and motion path. We used a SVM pattern classifier to identify the objects across the 80 animations both in independently identified regions of interest and in whole-brain searchlights. Despite sparse form information, the point-light condition showed above chance classification for object identity across multiple regions of both higher-level and retinotopic visual cortex. We also examined whether training on the point-light data was sufficient to support identity classification in the form-visible condition, and vice versa. For both analyses, we observed above-chance classification across similar regions of visual cortex. Thus, viewing form-visible animations and form reduced point-light animations of the same objects yields similar patterns of BOLD responses. The ability to decode dynamic object identity from point-light animations, and classify across point-light and form-visible stimuli, suggests that invariant kinematic information about object identity is encoded within a surprisingly wide set of regions within visual cortex.

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56.574 **The lateral occipital complex (LOC) shows viewpoint dependence in recognizing novel three-dimensional objects** Ying Yang[1], Carol A. Jew[1,2], Robert E. Kass[1,3,4], Michael J. Tarr[1,2]; [1]Center for the Neural Basis of Cognition, Carnegie Mellon University, [2]Department of Psychology, Carnegie Mellon University, [3]Department of Statistics, Carnegie Mellon University, [4]Machine Learning Department, Carnegie Mellon University

How view invariance is achieved in recognizing 3D objects has been a matter of some debate. To date, human functional neuroimaging studies of view invariance have been somewhat inconsistent in their results, reporting different levels of across-view tolerance within the object-selective, lateral occipital complex (LOC). Critically, many of these studies used familiar objects as stimuli, thereby confounding prior experience of multiple views with nominal view invariance in measured neural responses. Using fMRI, we investigated the encoding of object viewpoint within human LOC across different timepoints while learning novel 3D objects. In a learning phase, participants were trained to recognize the objects in two views separated by a 90 deg rotation in depth. Following extensive training, participants were asked to recognize the now-familiar objects in a generalization phase featuring four additional, novel views. MRI scans were run during the early and late stages of the learning phase, as well as the generalization phase. Surprisingly, within the LOC, we observed that the signal-to-noise ratio (SNR) of the BOLD response to the trained views decreased over learning, and, moreover, was negatively correlated with behavioral accuracy. Consistently, during generalization, the BOLD response to the two familiar views was significantly lower than the response to the four unfamiliar views, indicating that the observed learning effect was limited to familiar views. Finally, we applied linear support vector machine classifiers and found that the multivoxel patterns across the LOC showed above-chance discrimination of different views, suggesting that the LOC does carry information about object viewpoint. In sum, our results are consistent with the LOC encoding view-specific information about objects. Beyond this basic finding, the observed SNR reduction in the BOLD signal during training, which reflects a reduction of averaged neuronal activity, is suggestive of a shift towards sparser neural representations of objects with increasing familiarity.

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56.575 **Viewpoint invariant object recognition: Spatiotemporal information during unsupervised learning enhances generalization** Moqian Tian[1](moqiant@stanford.edu), Kalanit Grill-Spector[1,2]; [1]Psychology Dept., Stanford Univ., Stanford, CA, [2]Stanford Institute for Neuro-innovation and Translational Neuroscience, Stanford Univ., Stanford, CA

View invariant object recognition requires both binding multiple 2D views of an object and discriminating among different objects that are highly similar. However, it is unclear what information is learned during unsupervised learning to enable this ability. It has been hypothesized that spatiotemporal continuity between views during learning may be key for binding objects views to a single mental representation. We investigated this hypothesis across four experiments testing subjects' ability to discriminate among novel 3D objects across rotation, before and after training under two conditions: sequential: subjects were presented with 24 views of an object spanning 180° in sequential order providing spatiotemporal continuity, and random: subjects were presented with the same views, but in random order. Subjects showed significant improvement after training in discriminating views of 3D objects rotated in the image plane (Experiment 1, n=14,ΔAccuracy=27.6±1.5%,) or in depth (Experiment 2, n=20, ΔAccuracy=21.3±2.2%). Surprisingly, we found no differences in performance across sequential and random learning. In Experiment 3, we tested if implied motion serves as a cue to bind views by comparing training as before to training with masks placed between consecutive images reducing the implied motion. We found significant learning effects across all conditions (n=20, ΔAccuracy=21.0±3.4%), but no difference between masked and unmasked presentations. Finally, in Experiment 4 we tested subjects' ability to generalize their learning to new object views. Subjects were trained with seven views spanning 180° and tested on untrained views interpolated between the trained views. Results revealed that sequential learning improved generalization performance significantly more than random learning (ΔAccuracy sequential=18.5±2.6%, ΔAccuracy random=9.2±2.6%, n=26). Overall, our data shows that spatiotemporal information during unsupervised learning is not necessary for view invariant recognition, but can lead to better generalization when training with a small number of views.

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56.577 **Level of discrimination as an organizing principle in the human ventral occipito-temporal cortex for object recognition** Alan C.-N. Wong[1](alanwong@psy.cuhk.edu.hk), Yetta Kwailing Wong[2]; [1]Department of Psychology, The Chinese University of Hong Kong, [2]Department of Applied Social Studies, City University of Hong Kong

Regions of the ventral occipito-temporal (vOT) cortex show preferential activations to particular object categories, such as faces, words, tools and scenes. The origin of such category-selective activations has been a topic of intense debate. A functional magnetic resonance-adaptation (fMR-A) study was conducted to investigate one candidate principle governing the organization of the vOT – level of discrimination. It is hypothesized that the medial regions of the vOT, sensitive to coarse input to the periphery of the visual field, are suited for coarse discrimination, while the lateral regions of the vOT, sensitive to foveal input with a high acuity, are suited for more specific, fine discrimination. Participants judged the color of a series of novel, artificial objects (Ziggerins) presented in (i) same-object blocks, in which the same object was presented repeatedly; (ii) different-object blocks, in which highly similar objects from the same category were presented; and (iii) different-category blocks, in which different objects across categories were presented. In general vOT activity was the lowest for same-object blocks due to adaptation, and release from adaptation for different-object and different-category blocks was found due to small and large shape changes respectively. Importantly, the medial portion of the vOT showed a larger release from adaptation for different-category than different-object blocks; towards the more lateral portion of the vOT, release from adaptation became similar for the two types of blocks. In other words, going from the medial to the lateral vOT there was a continuous change of the sensitivity bias from rough to detailed shape discrimination. Results suggest that this level-of-discrimination map can be one of the many continuous maps contributing to the seemingly discrete category-selective regions.

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56.578 **Decoding visual object representation in human parietal cortex** Maryam Vaziri Pashkam[1](mvaziri.p@gmail.com), Yaoda Xu[1]; [1]Vision Sciences Laboratory, Department of psychology, Harvard University

Although visual object representation has been discovered in the primate parietal cortex more than a decade ago, the nature of this representation remains largely unknown. Using fMRI and multiple voxel pattern analysis, here we investigated the represetnation of objects from eight different categories in human parietal cortex. The categories we used included face, body, house, cat, elephant, car, chair and scissors. The parietal regions we examined included five topographic areas along the intra-parietal sulcus (IPS) as well as superior and inferior IPS, two regions previously implicated in visual object individuation and identification, respectively. We also examined responses from retinotopically defined early visual areas, the object shape processing region in lateral occipital cortex and part of temporal cortex activated by our object stimuli. During the experiment, observers saw a sequential presentation of ten exemplar objects from each category and detected an occcasional 1-back repetition of the object. Using a linear support vector machine classifier, we obtained significant decoding of the different object categories in both occipito-temporal and parietal regions. Decoding in these regions was unaffected by whether intact object images or images equalized in luminance, contrast and spatial frequency were used. Decoding in occipito-temporal and most of the parietal regions were also unaffected by object position and size changes. In contrast, size and position changes removed successful decoding in early visual cortex, consistent with the nature of visual information representation in that region. These results demonstrate that objects from different categories can be represented distinctively in human parietal cortex. This representation shows both position and size invariance and is equally robust when lower-level visual feature differences among the categories are removed. Object representation in human parietal cortex thus likely reflects high levels of visual object processing, similar to what was found in occipital and temporal cortices.

Acknowledgement: NIH grant 1R01EY022355 to Y.X.

56.579 **Hands in motion: Characterization of upper-limb selective regions in the occipito-temporal cortex.** Tanya Orlov[1](tanya.orlov@mail.huji.ac.il), Yuval Porat[1], Tamar Makin[3], Ehud Zohary[1,2]; [1]Neurobiology Department, Life Sciences Institute, Hebrew University of Jerusalem, Jerusalem 91904, Israel, [2]Interdisciplinary Center for Neural Computation and ELSC, Hebrew University of Jerusalem, Jerusalem 91904, Israel, [3]FMRIB Centre, Nuffield Department of Clinical Neuroscience, University of Oxford, Oxford OX39DU, UK

We report a region (termed here extrastriate arm area, EAA), in the occipito-temporal cortex (OTC), which shows clear preference to static images of human upper-limbs when compared to other body-parts or to other object categories. Such selectivity was previously attributed to shape aspects, which presumably vary across image categories. However, functional selectivity for upper-limbs may also be driven by their unique motion features. Here we show that in EAA selectivity to static upper-limb images and motion kinematics go hand in hand. Using resting-state and task-based functional MRI, we demonstrate that OTC voxels' preference to different image categories can be predicted, to a significant extent, from their patterns of functional connectivity. We find that the degree of OTC voxels' selectivity to rigid, typically inert objects is positively associated with their strength of functional connectivity with mid-level shape-selective areas (i.e. V4 / LO-1). Thus, representations of these objects within the OTC are likely to obey the accepted visual hierarchy scheme. Contrary to this scheme, we show that greater preference of OTC voxels to static pictures of upper-limbs coincides with their stronger functional connectivity with hMT+ (but not hV4 / LO-1). This suggests a tight link between upper-limb selectivity and motion processing. To corroborate this working hypothesis we created a set of natural arm movement videos, in which kinematic patterns were parametrically manipulated, while keeping shape parameters constant. Using multivariate pattern analysis, we show that the degree of (dis)similarity in arm velocity-profiles predicts, to a significant extent, the degree of (dis)similarity in multivoxel activation patterns, in both EAA and hMT+. Together, these results suggest that the functional specificity of EAA is at least partly determined by articulated visual motion. We propose that selectivity to static upper-limb images in the OTC may result from experience-dependent association between shape elements, which characterize upper-limbs, and upper-limb-specific motion patterns.

56.580 **Spatial attention and task relevance modulate neural responses to illusory contours at early and later stages respectively** Xiang Wu[1](rwfwuwx@gmail.com), Liang Zhou[1], Cheng Qian[1], Lingyu Gan[1], Daren Zhang[2]; [1]Department of Psychology, Sun Yat-Sen University, China, [2]CAS Key Laboratory of Brain Function and Disease, and School of Life Sciences, University of Science and Technology of China, Hefei, Anhui, China

The brain can effortlessly recognize objects even when visual information belongs to an object is widely separated. Whether such long-range visual completion depends on high-level cognitive processes is not well understood. Here we report separate modulations of spatial attention and task relevance on neural activities to the famous Kanizsa-type illusory contours (ICs): a contour (e.g., a diamond) is perceived even though the fragments of the contour are separated by gaps. Event-related potentials (ERPs) sensitive to ICs were modulated by spatial attention at an early stage (~ 160ms) and were modulated by task-relevance at a later stage (~260 ms), respectively. The present top-down attentional influences on IC perception provide direct neural evidence supporting the "cognitive view" that despite the automatic character of IC processing, high-level cognitive processes are necessary for IC perception. The results also suggest a two-stage attentional mechanism of IC perception: spatial attention is more involved in an early "postulating stage" in which a perceived IC is postulated based on spatial stimulus configuration; and task relevance is more engaged in an later " matching stage" in which the analyzed IC is compared with the postulated IC.

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56.581 **Misbinding of color and motion in human early visual cortex: an event-related potential study** Yanyu Zhang[1](yy.zhang@pku.edu.cn), Xilin Zhang[1], Fang Fang[1,2,3]; [1]Department of Psychology and Key Laboratory of Machine Perception (Ministry of Education), Peking University, [2]Peking-Tsinghua Center for Life Sciences, Peking University, [3]PKU-IDG/McGovern Institute for Brain Research, Peking University

Wu et al. (Nature, 2004) described a compelling illusion demonstrating a steady-state misbinding of color and motion. Here, we explored the neural mechanism of the misbinding. In the misbinding condition (MC), the stimulus contained two sheets of random dots, one sheet moving up and the other moving down. On the upward-moving sheet, dots in the right-end area were red and the rest dots were green. On the downward-moving sheet, dots in the right-end area were green and the rest dots were red. When subjects fixated at the stimulus center, they bound the color and motion of the dots in the right-end area erroneously – the red dots appeared to move downwards and the green dots appeared to move upwards. In the binding condition (BC), the stimulus was identical to that in the MC except that all red dots moved downward and all green dots moved upward. In the control condition (CC), no dot was presented in the right-end area. In the psychophysical adaptation experiment, we found a significant color-contingent motion aftereffect in the right-end area after adapting to the BC and MC, but not the CC. The aftereffect in the MC followed the prediction from the perceived binding of color and motion, rather than their physical binding. In the ERP adaptation experiment, we found a color-contingent motion adaptation effect reflected as a weaker C1 component after adapting to the BC and MC, but not the CC. The adaptation effect manifested in the C1 peak phase (57-79 ms) in the BC and in the late C1 phase (67-118 ms) in the MC. Dipole source localization showed that V1 and V2 made a major contribution in the two phases, respectively. Taken together, these findings suggest that feature binding and misbinding occur at early processing stages, but in different lower visual areas.

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56.582 **Edge co-occurrences are sufficient to categorize natural versus animal images** Laurent U Perrinet[1](laurent.perrinet@univ-amu.fr), James A Bednar[2]; [1]Institut de Neurosciences de la Timone (UMR7289), CNRS / Aix-Marseille Université, [2]Institute for Adaptive and Neural Computation, University of Edinburgh

Analysis and interpretation of a visual scene to extract its category, such as whether it contains an animal, is typically assumed to involve higher-level associative brain areas. Previous proposals have been based on a series of processing steps organized in a multi-level hierarchy that would progressively analyze the scene at increasing levels of abstraction, from contour extraction to low-level object recognition and finally to object categoriza-

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tion (Serre, PNAS 2007). We explore here an alternative hypothesis that the statistics of edge co-occurences are sufficient to perform a rough yet robust (translation, scale, and rotation invariant) scene categorization. The method is based on a realistic model of image analysis in the primary visual cortex that extends previous work from Geisler et al. (Vis. Res. 2001). Using a scale-space analysis coupled with a sparse coding algorithm, we achieved detailed and robust extraction of edges in different sets of natural images. This edge-based representation allows for a simple characterization of the ``association field'' of edges by computing the statistics of co-occurrences. We show that the geometry of angles made between edges is sufficient to distinguish between different sets of natural images taken in a variety of environments (natural, man-made, or containing an animal). Specifically, a simple classifier, working solely on the basis of this geometry, gives performance similar to that of hierarchical models and of humans in rapid-categorization tasks. Such results call attention to the importance of the relative geometry of local image patches in visual computation, with implications for designing efficient image analysis systems. Most importantly, they challenge assumptions about the flow of computations in the visual system and emphasize the relative importance in this process of associative connections, and in particular of intra-areal lateral connections.

Acknowledgement: BrainScaleS

56.583 The bottleneck in human letter recognition: A computational model

Avi Ziskind[1](avi.ziskind@gmail.com), Olivier Hénaff[2], Yann LeCun[2,3], Denis Pelli[1,2]; [1]Psychology Department, New York University, [2]Center for Neural Science, New York University, [3]Computer Science Department, New York University

Limitations of human letter recognition indicate a bottleneck in the combining of visual information to recognize a letter. Signal Detection Theory shows that the ideal observer for a signal in white noise does template matching, and its performance depends solely on the signal-to-noise ratio (SNR), independent of signal complexity. Surprisingly, human threshold SNR is proportional to letter complexity (Pelli et al. 2006), suggesting that only a limited number of features can be combined for identification. To better understand this limitation of human observers, we trained an artificial neural network to identify letters, hoping to discover what network design characteristics would make its threshold depend on complexity. We used a convolutional neural network (ConvNet), a popular multi-layer neural network architecture for object and letter recognition (LeCun et al. 1998). We created multiple sets of images consisting of a letter added to a Gaussian white-noise background, varying noise level across different sets. We used seven fonts, spanning a ten-fold range of complexity. For each font, we trained the network to identify letters, using all the noise levels together to train and then testing accuracy at each noise level to determine the threshold SNR required for 64% correct identification of new test images. With extensive resources, ConvNet has a much lower threshold than humans, and exhibits only a weak dependence on font complexity (with a log-log slope of 0.5). With restricted resources (two convolutional layers respectively containing 6 & 12 convolutional filters followed by 60 fully-connected units), the threshold of ConvNet rises to human levels (0.10 RMS error in log SNR threshold across 7 fonts) and a log-log slope of 1 (i.e. proportional). Thus we find that a ConvNet with restricted resources closely matches human thresholds for letter identification in seven fonts that span a tenfold range of complexity.

56.584 Event-related potentials show that semantic relations between objects are computed even under change blindness

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When changes in visual scenes occur after a brief visual disruption, observers remarkably often fail to detect even large changes. This so- called change blindness has often been interpreted as a result of impoverished visual information encoding or as a failure to compare the pre-change and post-change scene. In the present electroencephalography study, we investigated whether pre-change and post-change information can be compared unconsciously, even when observers are unaware that a change has occurred. If so, this would suggest that change blindness does not preclude high-level, semantic object processing. We presented scenes composed of natural objects in a change blindness paradigm in which one object changed from one presentation to the next. Object changes were either semantically related (e.g. rail car changed to rail) or unrelated (e.g. rail car changed to sausage). Observers were first asked to detect whether any change had occurred and then to judge the semantic relation of the two objects involved in the change. For semantically incongruent changes, we found an N400-like event-related potential (ERP) effect, i.e. a more negative-going ERP for semantically unrelated changes. Importantly, the N400 effect persisted even when observers were unaware of the change, rendering them unable to report the semantic relationship of pre-change and post-change object. The presence of a neuronal marker of semantic processing implies that even under change blindness, the identities of pre-change and post-change object are encoded and even processed up to the stage where their semantic relationship is computed. This finding suggests that 1) change blindness does not necessarily imply sparse visual representations, and 2) change blindness does not necessarily reflect a comparison failure of the pre-change and post-change scene. In sum, the encoding and processing of visual information under change blindness is by far less impoverished as previously believed.

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56.585 Right Hemisphere Dominance in Nonconscious Processing

Jing Chen[1](jinghku@hku.hk), Janet Hsiao[1]; [1]Department of Psychology, University of Hong Kong

Here we examined hemispheric differences in conscious and nonconscious perception using a repetition priming paradigm. In experiment 1, participants judged the direction of a target arrow (either left- or right-pointing), which was preceded by a prime arrow in either the left visual field (LVF) or the right visual field (RVF). The congruency effect was assessed as the response time difference between the congruent condition (the prime and the target pointed to the same direction) and the incongruent condition (they pointed to opposite directions). The prime was either masked or unmasked. Participants reported unaware of the prime in the masked condition. We found a significant congruency effect when the prime was presented in the LVF/right hemisphere (RH) but not the RVF/left hemisphere (LH) in the masked (subliminal) condition. In contrast, in the unmasked (supraliminal) condition, the RVF prime had a stronger congruency effect than the LVF prime. In experiment 2, the same procedure was used; we manipulated the prime duration from 10, 20, 30, 40 to 50 ms. A backward mask was used in all trials. Subliminal conditions were those in which d-prime measures were not significantly above zero (10, 20, and 30ms conditions for LVF primes; 10 and 20ms conditions for RVF primes). An interaction between visual field and awareness was found: LVF primes but not RVF primes generated a congruency effect in the subliminal condition, whereas in the supraliminal condition, RVF primes had a bigger congruency effect than LVF primes. Taking together, our results revealed a LH/RH distinction in conscious/nonconscious perception of directional information. This result suggests a dominant role of the RH in nonconscious processing, and is consistent with Baynes and Gazzaniga's (2000) argument that the RH has an advantage in shaping behavior with implicit information whereas the LH plays a greater role in expressing explicit knowledge.

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56.586 Repetition probability effects depend on prior experiences

Mareike Grotheer[1,2](mareike.grotheer@uni-jena.de), Gyula Kovács[1,2,3]; [1]Institute of Psychology, Friedrich-Schiller-University of Jena, Jena, Germany, [2]DFG Research Unit Person Perception, Friedrich-Schiller-University of Jena, Jena, Germany, [3]Department of Cognitive Science, Budapest University of Technology and Economics, Budapest, Hungary

The predictive coding (PC) model of perceptual inferences (Rao and Ballard, 1999) proposes that perceptions are the result of a continuous comparison of perceived and predicted events. Recently, PC has also been proposed as a possible mechanism of repetition suppression (RS; the diminished neuronal signal for repeated stimuli when compared to non-repeated stimuli); it has been shown, that the repetition related reduction of the blood-oxygen level dependent (BOLD) signal, measured by functional magnetic resonance imaging (fMRI) techniques, is modulated by repetition probability (P(rep)) for faces (Summerfield et al., 2008). Surprisingly, however, other studies, using non-face stimuli, could not find P(rep) dependent modulations of RS, in either macaque single-cell activity of the inferior-temporal cortex (Kaliukhovich and Vogels, 2012), or in measuring the BOLD signal in the Lateral Occipital Complex (LO; Kovács et al., 2013) of human observers, limiting the validity of PC explanations of RS to the category of faces. To address the issue of category selectivity of P(rep) modulations of RS, here we tested letters of the roman alphabet, as well as, unknown false-fonts as control stimuli. We modulated P(rep) for pairs of stimuli in individual blocks and observed a significant RS for both stimulus sets in the Letter Form Area (LFA), as well as, in the caudal-dorsal part of the LO. Interestingly, we found P(rep) modulations only on the RS for roman letters, but not for false-fonts. Our findings suggest that P(rep) effects on RS depend on the prior experience of the subjects with the applied stimulus category.

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Wednesday Morning Talks

Color and light: Surfaces and materials

Wednesday, May 21, 8:15 - 9:45 am
Talk Session, Talk Room 1
Moderator: Bart Anderson

61.11, *8:15 am* **The Perception of Surface Material from Disparity and Focus Cues** Martin Banks[1,2](martybanks@berkeley.edu), Abdullah Bulbul[1], Rachel Albert[1], Rahul Narain[3], James O'Brien[3], Gregory Ward[4]; [1]Vision Science Graduate Group, UC Berkeley, Berkeley CA 94720, [2]School of Optometry, UC Berkeley, Berkeley CA 94720, [3]Department of Computer Science, UC Berkeley, Berkeley CA 94720, [4]Lawrence Berkeley National Laboratory, Berkeley CA 94720

The visual properties of surfaces reveal many things including a floor's cleanliness and a car's age. These judgments of material are based on the spread of light reflected from a surface. The bidirectional reflectance distribution function (BRDF) quantifies the pattern of spread and how it depends on the direction of incident light, surface shape, and surface material. Two extremes are Lambertian and mirrored surfaces, which respectively have uniform and delta-function BRDFs. Most surfaces have more complicated BRDFs and we examined many of them using the Ward model as an approximation for real surfaces. Reflections are generally view dependent. This dependence creates a difference between the binocular disparities of a reflection and the surface itself. It also creates focus differences between the reflection and physical surface. In simulations we examined how material type affects retinal images. We calculated point-spread functions (PSFs) for reflections off different materials as a function of the eye's focus state. When surface roughness is zero, the reflection PSF changes dramatically with focus state. With greater roughness, the PSF change is reduced until there is no effect of focus state with sufficiently rough surfaces. The reflection PSF also has a dramatic effect on the ability to estimate disparity. We next examined people's ability to distinguish surface markings from reflections and to identify different types of material. We used a unique volumetric display that allows us to present nearly correct focus cues along with more traditional depth cues such as disparity. With binocular viewing, we observed a clear effect of the disparity of reflections on these judgments. We also found that disparity provided less useful information with rougher materials. With monocular viewing, we observed a small but consistent effect of the reflection's focal distance on judgments of markings vs. reflections and on identification of material.
Acknowledgement: NIH

61.12, *8:30 am* **Looking against the light: how perception of translucency depends on lighting direction and phase function** Bei Xiao[1](beixiao@mit.edu), Bruce Walter[2], Ioannis Gkioukelas[3], Todd Zickler[3], Edward Adelson[1,4], Kavita Bala[2]; [1]Department of Brain and Cognitive Sciences, MIT, [2]Program of Computer Graphics, Cornell University, [3]Harvard School of Engineering and Applied Sciences, Harvard University, [4]Computer Science and Artificial Intelligence Laboratory, MIT

Translucency is an important aspect of material appearance. To some extent, humans can estimate translucency in a consistent way across different shapes and lighting conditions, i.e., to achieve translucency constancy. However, Fleming and Bülthoff (2005) have shown that there can be large failures of constancy with respect to lighting direction changes. Here, we explore the interaction of shape, illumination, and degree of translucency constancy more deeply, by including in our analysis the variations in translucent appearance that are induced by the shape of the scattering phase function. This is an aspect of translucency that has been largely neglected. We used appearance matching to measure how perceived translucency depends on both lighting and phase function. The stimuli were rendered scenes that contain a figurine and the lighting direction is represented by a spherical harmonic basis function. Observers adjusted density of a match figurine under one lighting condition to match the material property of a target figurine under another lighting condition. Across the trials, we varied both the lighting direction and the phase function of the target. The phase functions were sampled from a 2D space that captures most of the perceptual variation in appearance (Gkioulekas et al. 2012). We find that degree of translucency constancy depends strongly on the phase function's location in the 2D space, suggesting that the space captures useful information about different types of translucency. We compare the case of a torus, which has a simple smooth shape, with that of the figurine, which has more complex geometric features. The complex shape shows a greater range of apparent translucencies, and also a higher degree of constancy failure. In summary, humans show significant failures of translucency constancy across changes in lighting direction, but the effect depends both on the shape complexity and the translucency phase function.
Acknowledgement: NSF award 1161731

61.13, *8:45 am* **The Dark Secrets of Dirty Concavities** Roland Fleming[1](roland.w.fleming@psychol.uni-giessen.de), Steven Cholewiak[1]; [1]Experimental Psychology, University of Giessen

Cracks, crevices and other surface concavities are typically dark places where both dirt and shadows tend to get trapped. By contrast, convex features are exposed to light and often get buffed a lighter or more glossy shade through contact with other surfaces. This means that in many cases, for complex surface geometries, shading and pigmentation are spatially correlated with one another, with dark concavities that are dimly illuminated and lighter convexities, which are more brightly shaded. How does the visual system distinguish between pigmentation and shadows when the two are spatially correlated? We performed a statistical analysis of complex rough surfaces under illumination conditions that varied parametrically from highly directional to highly diffuse in order to characterise the relationships between shading, illumination and shape. Whereas classical shape from shading analyses relate image intensities to surface orientations and depths, here, we find that intensity information also carries important additional cues to surface curvature. By shifting the phase of dark portions of the image relative to the surface geometry, we show that the visual system uses these relationships between curvatures and intensities to distinguish between shadows and pigmentation. Interestingly, we also find that the visual system is remarkably good at separating pigmentation and shadows even when they are highly correlated with one another, as long as the illumination conditions provide subtle local image orientation cues to distinguish the two. Together, these findings provide key novel constraints on computational models of human shape from shading and lightness perception.
Acknowledgement: NSF-BMBF Joint Program in Computational Neuroscience (FKZ: 01GQ1111)

61.14, *9:00 am* **Perception of specular materials coupled to perceived 3-D shape** Phillip Marlow[1](phillip.marlow@sydney.edu.au), Dejan Todorović[2], Barton Anderson[1]; [1]Department of Psychology, University of Sydney, Australia, [2]Department of Psychology, Laboratory of Experimental Psychology, University of Belgrade, Serbia

One of the fundamental problems of material perception involves understanding how the visual system identifies the physical causes of image structure. Previous research into the perception of specularity has attempted to identify particular image properties that elicit percepts of specularity. Here, we show that identical luminance gradients can generate a percept of either a matte or specular surface depending on the surface's perceived 3D geometry. Methods. In Experiment 1, we generated 1D-grating patterns and parametrically varied the steepness of the luminance gradients. We induced changes in perceived 3D shape by varying the shape of the bounding contours. One pattern contained a sinusoidal contour that was half the grating's frequency, whereas the other was a sinusoidal contour with the same frequency of the grating. Experiment 2 manipulated the shape of 3D surfaces in order to induce analogous transformations as our grating stimuli, which was used to test multiple models of the differences in specularity we observed in Experiment 1. Observers performed specular rating judgments and paired comparisons for both experiments. Results. The 3D shape differences induced by either the sinusoidal bounding contours (Experiment 1) or the 3D stimuli (Experiment 2) induced compelling differences in the perceived specularity of identical luminance gradients. The results of Experiment 2 revealed that the critical factor modulating these differences was the perceived surface curvature in the vicinity of the luminance maxima (potential specular highlights): Surfaces that appear to contain a broader range of surface normals in these neighbourhoods appeared less specular than surfaces with a narrower range of surface normals. These results were supported by Monte Carlo simulations of matte and specular surfaces in natural light fields. Conclu-

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sions. Our results demonstrate that the visual system utilizes mid-level representations of surface shape to estimate the reflectance properties of matte and specular surfaces from otherwise identical image structure.

61.15, *9:15 am* **Estimation of angular velocity of objects differing in material is inconsistent** Gizem Kucukoglu[1](gizemkucukoglu@gmail.com), Laurence T Maloney[1,2]; [1]Psychology Department, New York University, [2]Center for Neural Science, New York University

Previously, we demonstrated that there is an interaction between object surface material and perception of angular velocity (Kucukoglu, Maloney, 2013): specular objects were judged to be moving faster than matte (Lambertian) objects matched in rotational velocity. This year we considered three classes of objects: specular, matte, and matte with albedo surface texture. The stimuli were irregular, blob-like shapes rendered with specular, matte or textured materials. Their angular velocity ranged between 6°/sec to 84°/sec. We had three conditions: (1) textured vs. specular, (2) specular vs. matte and (3) textured vs. matte. In all of these conditions, on a given trial subjects saw a pair of rotating objects – e.g. one specular, one textured – presented one after the other. The task was to pick the faster rotating object in the pair. We used a staircase paradigm to adjust the angular velocity of the objects to the point of subjective equal angular velocity.Three out of four subjects in condition 1 show a significant bias in perceiving textured objects to be faster than the specular objects. Condition two is a repetition of our previous task but this time with slower angular velocities. Two out of four subjects in condition 2 show a bias towards perceiving specular objects to be faster than matte objects. If textured is perceived to be faster than specular (A>B) and specular is faster than matte (B>C) we would expect to find a bias towards perceiving textured to be faster than matte (A>C). However, we do not find any significant bias between textured and matte objects (we do not reject A=C for any subject). We present a cue integration model of estimation of angular velocity proposing that dynamic reweighting of different cues to angular velocity accounts for the observed intransitivity.

Acknowledgement: NSF1059166

61.16, *9:30 am* **Complementary development of material perception and image discrimination in infants** Isamu Motoyoshi[1], Jiale Yang [2], So Kanazawa[3], Masami K. Yamaguchi[2]; [1]Department of Life Sciences, The University of Tokyo, [2]Department of Psychology, Chuo University, [3]Department of Psychology, Japan Women's University

Matured visual system extracts invariants from natural images to estimate properties of external objects such as shape and material, meanwhile it discounts information variant with viewpoint and illumination. For instance, we easily judge the glossiness of a surface, but rarely care about the reflected pattern of a scene (lightfield) on the surface (visual equivalence: Ferwada, 2008). To understand when and how such a computational scheme is acquired during development, we examined whether infants aged 3-8 months can detect changes in the surface glossiness and changes in the reflected lightfield that adults cannot see. Two pairs of computer-generated images were used: one pair consisted of glossy and matte images rendered from the same 3D object, and another pair consisted of two glossy images rendered with two slightly different lightfields. One pair of these two was presented alternately with a 200 ms ISI (change images) in one side. In the other side, an image chosen from the corresponding image pair was presented repeatedly (no-change images). We measured the spontaneous preference of infants for the changing images over the no-change images. The results showed that infants aged 7-8 months, but not 3-6 months, preferred the change in the surface glossiness. In contrast, infants aged 3-4 months, but not 5-8 months, preferred changes in the reflecting lightfield. Proportion of preferential looking was correlated with the month of age positively for the surface change (r=0.529) and negatively for the lightfield change (r=-0.504). Similar results were obtained for stimuli synthesized using Portilla-Simoncelli's algorithm. These findings support the notion that the visual system declines from reacting directly to image inputs at 5-6 months old as it complementarily develops to represent external surfaces or relevant image statistics at 7-8 months old.

Acknowledgement: MEXT/JSPS KAKENHI (22135004, 25135729, 21243041)

Individual differences

Wednesday, May 21, 8:15 - 9:45 am
Talk Session, Talk Room 2
Moderator: Jeremy Wilmer

61.21, *8:15 am* **Behavioral face recognition performance correlates with an electrophysiological index of individual face discrimination obtained by fast periodic oddball stimulation** Buyun Xu[1](xubuyun@uvic.ca), James Tanaka[1], Bruno Rossion[2], Joan Liu-Shuang[2]; [1]Department of Psychology, University of Victoria, [2]Face categorization lab, University of Louvain, Belgium

The current study measured electrophysiological response to periodic oddball stimulation of faces (Liu-Shuang et al., 2013) from 34 participants, and correlated the magnitude of this visual response with face recognition performance as measured by the Cambridge Face Memory Test (CFMT, Duchaine & Nakayama, 2006). During a stimulation sequence, a face picture (A) was presented at the frequency of 6 Hz (F, 6 faces/second) for 60-seconds, with different oddball faces (B, C, D…) being presented at every 5th cycle (F/5=1.2 Hz) (i.e., AAAABAAAACAAAAD....). In the electroencephalogram (EEG) recorded from only 4 trials of stimulation (60-seconds each), the generic visual responses associated with the general neural responsiveness to the periodic stimulation emerged at 6 Hz and harmonics (12 Hz, 18 Hz, etc.) in all 32 channels, with the largest responses over medial occipital locations. The specific responses at 1.2 Hz and harmonics (2.4 Hz, 3.6 Hz, etc.) specifically indexing individual face discrimination were also present, peaking over occipito-temporal locations (as in Liu-Shuang et al., 2013). The magnitude of the generic component at the medial occipital locations did not correlate with CFMT score (r=-0.27, p=0.14). However, the magnitude of the specific component at occipital-temporal locations showed a trend to be significantly correlated with the CFMT score (r=0.32, p=0.08). This correlation reached significance (r=0.40, p=0.02) when individual differences in the general neural responsiveness to periodic stimulation were taken into account by normalizing (i.e., dividing) the magnitude of the specific response with that of the generic response. Overall, these findings suggest that, without an explicit face discrimination task, the electrophysiological response elicited by the periodic oddball stimulation is able to provide a reliable neural index of individual differences in face recognition ability.

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61.22, *8:30 am* **Independent ensemble processing mechanisms for high-level and low-level perceptual features** Jason Haberman[1](haberman@wjh.harvard.edu), Timothy F. Brady[1], George A. Alvarez[1]; [1]Department of Psychology, Harvard University

The ability to extract a summary representation for a group of related objects (ensemble perception) operates across a host of visual domains: People can readily perceive the average emotion of crowds of faces, the average size of dots, and the average orientation of Gabors. Do these ensemble representations rely on a common underlying mechanism, or are there separate ensemble processing mechanisms for different stimulus domains? Here, we address this question using an individual differences approach. In a series of experiments, we assessed performance on pairs of ensemble dimensions, including high-level dimensions (facial expression, facial identity, animal shape) and low-level dimensions (Gabor orientation, triangle orientation, color). For example, some participants saw sets of faces and sets of oriented Gabors, while other participants saw sets of Gabors and sets of oriented triangles. Each set (e.g., 4 faces) was displayed for one second, after which participants adjusted a test item to match the average feature (e.g., average expression) of the preceding set. We measured the error in responses for each feature dimension, and then correlated performance on the two features across subjects (N=100 per experiment). The results revealed a striking disconnect between high-level and low-level ensemble domains. For example, performance in representing average facial identity did not predict performance in representing average orientation (r=0.20; no higher than the correlation with an unrelated non-ensemble task). In contrast, performance within high-level domains was strongly correlated (e.g., average identity vs. average animal shape, r=0.72), as was performance within low-level domains (e.g., average triangle orientation vs. average color, r=0.66). Overall, these experiments reveal that the cognitive architecture of ensemble perception reflects a strong divide between high-level and low-level feature domains. This division could reflect perceptual noise that is correlated within but not across levels, or the existence of separate high-level and low-level ensemble mechanisms.

Acknowledgement: NSF CAREER BCS-0953730 to G.A.A.

61.23, *8:45 am* No action video game training effects for multiple object tracking or mental rotation Anika Guha[1](aguha@wellesley.edu), Amyeo Jereen[1], Joseph DeGutis[2], Jeremy Wilmer[1]; [1]Wellesley College, [2]Boston VA

A large and rapidly growing literature suggests that playing action video games may enhance a range of cognitive capacities (Powers et al, 2013). This literature, however, has recently been criticized for methodological shortcomings, including inadequate blinding (e.g. Boot et al, 2012). Two of the most highly cited studies reported successful training of mental rotation (MRT; Feng et al, 2007) and multiple object tracking (MOT; Green & Bavelier, 2006). The only published attempt to replicate these findings found no training effect (Boot et al, 2012), yet this study did not document sufficient reliability in its MRT and MOT tests to detect a training effect. We attempt here to replicate the original training effects with highly reliable MRT (alpha=0.82) and MOT (alpha=0.82) tests. We used the same action video game as the prior studies (Medal of Honor, MOH, a first-person shooter), plus matched action (Wii Sports) and non-action (World of Goo, strategy game) control training games and a no-training control (NTC). We carefully blinded participants to our hypotheses, and an extensive post-training questionnaire confirmed that this blinding succeeded. Conditions did not differ significantly in their pre/post difference for either MOT ($F(3,76)=0.93$, $p=0.43$) or MRT ($F(3,77)=1.96$, $p=.13$), and no active training condition improved significantly more than the NTC on either measure. Surprisingly, MOH improved numerically (though not significantly) less than all other conditions for both measures. In sum, our carefully controlled, blinded study failed to replicate two key benefits reported for action video game training, despite highly reliable measures. It is possible that the original reports of positive training effects for MRT and MOT were due to insufficient blinding or random chance. Our results suggest that action video game playing has less influence on MRT and MOT than those prior results implied.

Acknowledgement: Brachman Hoffman Fellowship to JW

61.24, *9:00 am* Global Motion, Mathematics and Movement: Dorsal Stream Sensitivity Relates to Children's Individual Differences in Cognitive Abilities and Regional Brain Development Janette Atkinson[1](j.atkinson@ucl.ac.uk), Oliver Braddick[2], John Wattam-Bell[1], Natacha Akshoomoff[3,4], Erik Newman[3], Holly Girard[5], Anders Dale[6,7], Terry Jernigan[3,4,6,8]; [1]Developmental Science, University College London, [2]Experimental Psychology, Univerity of Oxford, [3]Center for Human Development, University of California San Diego, [4]Psychiatry, UCSD, [5]SDSU/UCSD Joint Doctoral Program in Clinical Psychology, [6]Radiology, UCSD, [7]Neurosciences, UCSD, [8]Cognitive Science, UCSD

In many different developmental disorders, global motion sensitivity is impaired relative to global form. These complementary measures of extrastriate function reflect processing in the dorsal and ventral streams respectively, suggesting a general 'dorsal stream vulnerability' (Braddick et al, Neuropsychologia 2003) associated with deficits on visuo-motor, spatial, and attentional tasks. These associations have not previously been investigated in typically developing children. As part of the large scale PLING study (Pediatric Longitudinal Imaging, Neurocognition and Genetics), we measured global motion and form thresholds in 120 typically developing children (ages 6 -12 years) and examined their relation to a range of cognitive abilities, and to quantitative MRI measures of regional brain development. Correlations were calculated after adjustment for age effects. Children's global motion thresholds showed highly significant correlations ($p<0.0001$) with visuo-motor integration (VMI test, shape copying), rapid object naming (CTOPP test), and nonword reading (Woodcock-Johnson Word Attack) and at $p<0.002$ with mathematical achievement (Woodcock-Johnson Calculation) and phonological segmentation (CTOPP elision test). Global form thresholds were not significantly correlated with these but were correlated with working memory scores ($p<0.005$). Both thresholds, but motion more strongly, correlated with NIH Cognition Toolbox tests of reading, vocabulary, and executive function. We computed association maps of cortical surface area at each vertex with age- and gender-adjusted coherence thresholds. Higher form and motion coherence sensitivities were both associated with regional expansion of temporal, parietal and premotor cortex relative to the cuneus region. Within this relatively expanded area, form and motion coherence are associated with distinct patterns of regional differences. These variations may reflect differential trajectories of cortical development, or age independent individual differences in regionalization. Overall, in line with its vulnerability in disorders, dorsal stream function, as tapped by global motion sensitivity, is closely associated with many cognitive abilities, particularly in the visuospatial, mathematical, and phonological domains.

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61.25, *9:15 am* Peak frequency of induced gamma-band response to simple stimulus predicts individual switch rate for perceptual rivalry tasks. Jeremy Fesi[1](jeremy.fesi@mail.mcgill.ca), Janine Mendola[1]; [1]Department of Ophthalmology, McGill University

The peak frequency of an induced gamma-band response to a simple stimulus is known to vary across individuals (Muthukumaraswamy et al., 2010) and is thought to be shaped by differences in the extent of inhibitory connections in visual cortex (Brunel & Wang, 2003). In support of this, peak gamma frequency has been found to predict individual levels of resting state GABA in visual cortex (Edden et al., 2009; Muthukumaraswamy eta l., 2009). Also varying reliably across normal populations is the rate of alternation for perceptual rivalry tasks including binocular rivalry and monocular pattern rivalry (Carter & Pettigrew, 2003; Miller et al., 2010). Models of perceptual rivalry include mutual inhibition as a constraint on switching dynamics (e.g., Wilson 2003), but do the differences in switch rate reflect individual differences in cortical inhibition? If so, individual switch rate should be inversely correlated with peak gamma frequency, yet this prediction has not been tested. We used magnetoencephalography (MEG) to compare the peak gamma-band frequency of neuromagnetic responses of 12 healthy adults (6 female) to the onset of simple grating stimuli with their individual switch rates for binocular and monocular rivalry tasks. We computed Morlet wavelet analyses for left and right V1, V2, and MT+ of individual source data based on minimum norm estimates for each participant. Peak frequency was determined for three latency ranges: evoked (10-150ms), early induced (200-450ms) and late induced (500-800ms). Results show significant inverse correlations between peak frequency of early induced gamma in V1 and switch rate for both rivalry tasks, compatible with models that propose inhibitory connections in visual cortex are crucial for tuning gamma-band frequency as well as perceptual alternation rate. Our study suggests that subtle variations of behavior in a normal population can directly advance our understanding of visual function by encouraging models at increasingly finer scales.

Acknowledgement: Supported by an NSERC Discovery Grant to Janine Mendola.

61.26, *9:30 am* Individual Differences in Priors and Sensory Noise Explain Rates of McGurk Fusion Perception John Magnotti[1](john.magnotti@gmail.com), Michael Beauchamp[1]; [1]Department of Neurobiology & Anatomy, University of Texas Medical School at Houston

In the McGurk effect, incongruent auditory and visual syllables are perceived as a third, completely different syllable. Recent evidence suggests that there is a great deal of variability in the level at which the effect is perceived across different stimuli and different individuals. We describe a new model to characterize these differences based on the framework of Bayesian perceptual modeling. Three types of parameters are used: two for each participant (sensory noise and a fusion threshold) and one for each stimulus (the stimulus fusion strength). By incorporating sensory noise, the model is able to account for variability within individuals across multiple presentations of the same stimulus. Together with the threshold parameter, the sensory noise parameter explains variable responses to the same stimulus across participants; the stimulus strength parameter accounts for variable responses to different stimuli across participants. The model accurately described behavior in a dataset of 165 participants viewing up to 14 different McGurk stimuli. We demonstrate the utility of model by using it to explain apparently contradictory results in the literature about the prevalence of the McGurk effect in children with autism spectrum disorder. By separately estimating participant and stimulus parameters, the model eliminates the confound of stimulus differences to allow for both prediction and comparison of McGurk effect perception.

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Motion Perception: Biological, adaptation and higher order

Wednesday, May 21, 10:45 am - 12:30 pm
Talk Session, Talk Room 1
Moderator: Derek Arnold

62.11, *10:45 am* **Ventral "form" visual pathway and the EBA are not critical for biological motion perception: evidence from patients and a model suggestion** Sharon Gilaie-Dotan[1](shagido@gmail.com); [1] UCL Institute of Cognitive Neuroscience, London, UK

Different posterior brain regions are consistently activated when viewing body movements or static body images (pSTS, FBA, and EBA), yet their distinct functional roles including how they code information remains elusive. Our results from five patients with ventral visual lesions and control groups (including n>50 brain damaged patients without ventral cortex damage (Saygin 2007)) indicate that ventral visual cortex is not critical for the perception of and sensitivity to biological motion, as evident from the patients' effortless recognition of point light displays and their normal perceptual thresholds. Lesion delineation indicates that EBA or FBA damage does not impair biological motion perception. In contrast, these patients have form perception deficits and cannot recognize people from full-body static images. pSTS is rather spared in these patients. Following these and previous findings I propose a model that outlines the functional contributions of pSTS to biological motion recognition, and of EBA and FBA to human body recognition: While the integrity of pSTS is critical for biological motion recognition, the integrity of EBA and FBA is critical for recognizing human bodies. More generally, pSTS processes the motions/kinematics of self-moving objects, partially by relying on low-resolution static body-in-motion snapshots within it. The EBA engages in visual representation of biologically-moving objects, and perhaps of other self-moving objects. Fusiform regions engage in high-resolution visual representation of all object types, with enhanced representation of self-moving objects due to the varying appearances caused by their self-motion. The model posits that these representations are based on and modulated by experience/familiarity, explaining the sensitivities to biological motion [human body] in pSTS [EBA/FBA], the human biological motion inversion effect (absence of exposure to inverted stimuli leads to absence of representation), and findings in clinical populations. Furthermore, the model provides testable predictions for future research.

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62.12, *11:00 am* **Shifty Shades of Gray: Perceiving Motion from Deletion in the Shifty Shade Illusion** Karen B Schloss[1](karenschloss@gmail.com), Methma Udawatta[2]; [1]Department of Cognitive, Linguistic, and Psychological Sciences, Brown University, [2]Department of Neuroscience, Brown University

We present the shifty shade illusion, a new motion illusion with important implications for computing correspondences in apparent motion displays. Participants reported 2AFCs or ratings of perceived motion after a sequence of two frames. Frame 1 (F1) contained a rectangle divided into 12 vertical bars, consisting of 4 repetitions of a luminance triplet of light (L), medium (M) and dark (D) bars (e.g., LMDLMDLMDLMD) against a homogeneous background of one of 12 luminance levels (black to white). All six possible luminance orderings within the triplets were tested. In Frame 2 (F2), the center bar within each triplet was deleted, revealing the background. When L-bars were deleted in F2 against dark backgrounds (>.6 Michelson contrast from white), participants perceived motion toward the M-bars in the F1-F2 transition, whereas they perceived no motion when the L-bars were deleted against light backgrounds (<.6 contrast). Deleting the D-bars had the opposite effect, producing motion toward the M-bars against light backgrounds and no motion against dark backgrounds. Deleting the M-bars always caused motion percepts, behaving like L-bars on dark backgrounds and D-bars on light backgrounds. The illusion persists when there is no change in contrast polarity across edges from F1 to F2, suggesting it is not a case of reversed phi (Anstis, 1970). The results are better predicted by the change in contrast asymmetry between the center region's left and right edges from F1 to F2 (r=.92) than by Adelson and Bergen's (1985) motion energy model (r=.74). For example, rightward motion was perceived when the degree to which the center bar contrasted more with the right bar than the left bar was greater in F2 than in F1. This edge-based pattern persisted even when surface-based luminance correspondence predicted otherwise. The results suggest that edge-based correspondences are more influential than surface-based correspondences in determining motion perception.

62.13, *11:15 am* **The illusory brightening MAE separates low-level motion models.** Alan Johnston[1](a.johnston@ucl.ac.uk), Rupal Shah[1], Peter Scarfe[2]; [1]Cognitive, Perceptual and Brain Sciences, University College London, [2]School of Psychology & Clinical Language Sciences, University of Reading

The brightening MAE provides a challenge to low-level motion models. Introduced by Anstis (1967, Science 155 710-712), uniform fields appear to brighten after adaptation to repeated darkening. When the uniform test field is replaced by a spatial gradient, observers report illusory motion. We first measured the apparent speed of the aftereffect. Observers adapted to a circular pattern of linearly lightening or darkening radial segments, which were later replaced by static luminance gradients. When brightening or darkening, the adjacent segments of the dynamic pattern were set to grey so that any local motion energy at the boundaries was balanced over the adaptation period. At test, the sign of the spatial gradient was chosen appropriately for each segment to deliver uniform rotational motion. We found that the perceived speed of the rotation was precisely inversely proportional to the spatial gradient, as predicted by a spatiotemporal gradient motion computation. Motion energy models employ spatially band-pass front-end filters and therefore will not respond to uniform fields (the even Gabor is an exception). However, if the temporal brightening and spatial luminance gradient were combined before motion analysis, motion at test might be predicted by alternative models. To separate the models we sculpted the profile, introducing non-zero higher-order spatial derivatives. We now observed an apparent slowing of the aftereffect, which increased in turn with the accumulation of higher orders of spatial derivative for both convex and concave luminance ramps. Crucially, computer simulation shows the energy model and the multichannel gradient model predict increased speed from a simple addition of temporal brightening and the test spatial pattern. The data however are consistent with an isolated spatially low-pass first temporal derivative component delivering brightening, divided by multiple spatial derivatives introduced in the test pattern, a previously proposed multichannel gradient architecture, resulting in slowing of perceived speed.

Acknowledgement: BBSRC

62.14, *11:30 am* **What determines the adaptation rate in the visual motion aftereffect?** Loes van Dam[1](Loes.van_dam@uni-bielefeld.de), Marc Ernst[1]; [1]Cognitive Neurosciences, Faculty of Biology/CITEC, Bielefeld University

The visual Motion After-Effect (MAE) is mostly investigated from a neurophysiological point of view. Here we take a more ecological/functional perspective of the MAE representing a shift in the reference of zero motion. Surprisingly, little is known how this reference shifts over time and how the adaptation rate depends on the statistical properties of the stimuli. An optimal adaptor, like the Kalman Filter, would adapt more slowly with increased levels of noise in the adapting signal. Furthermore, the Kalman Filter predicts faster adaptation after exposure to high noise motion stimuli, because higher noise prior to adaptation would lead to a higher degree of uncertainty in the initial motion estimate. To test these hypotheses, participants watched sequences of alternating adaptation (3 sec) and test stimuli (0.5 sec). For the adaptation stimulus, randomly distributed dots could either move in different directions (Von Mises noise on direction), or at different speeds (Gaussian noise on speed). Three noise levels were tested for both types of noise: zero, medium, or high. Test stimuli consisted of stationary limited-life-time dots. Participants reproduced the illusory motion perceived for test stimuli on a graphics tablet, thus indicating both aftereffect direction and strength. Halfway in each sequence we changed both the noise level and the motion direction of the adapting stimulus in order to investigate how quickly the MAE would be consistent with the new motion stimulus. We found that noise within the adaptation stimulus slows down the adaptation rate. More interestingly, when switching between different levels of noise within the sequence, the noise before such a switch influenced adaptation rates after the switch. If the initial noise level was high, adaptation was faster after the switch and vice versa. These results indicate that, at a perceptual level, MAE adaptation rates behave in a manner consistent with an optimal adaptor.

62.15, *11:45 am* **Motion-dependent filling-in at the blind spot** Gerrit Maus[1](maus@berkeley.edu), David Whitney[1]; [1]University of California Berkeley

Stimuli extending through the receptor-free blind spot region of the retina appear filled in. However, stimuli extending into the blind spot without passing through to the opposite side appear cut off at the blind spot boundary. Here we test whether the perceived cut-off position at the blind spot boundary is solely determined by the anatomical position of the blind spot, or whether it can be influenced by visual motion. We used a haploscopic setup that allowed presenting stimuli independently to each eye. A sinusoidal grating was presented within a rectangular aperture that extended into the blind spot (or—for control purposes—ended in a Gaussian contrast edge at corresponding regions in the fellow eye). The grating was either drifting into or out of the blind spot region, or remained stationary while flickering in counterphase. Observers were asked to judge the perceived end point of the grating by moving pointers to the perceived cut-off position (presented binocularly next to the grating). In the fellow eye, the perceived end point was consistently shifted in the direction of motion, a replication of the well-known De Valois effect. At the blind spot, observers also perceived the cut-off point shifted in the direction of motion, meaning that observers perceived the grating extending further into the blind spot when it drifted in that direction. This result points to a dynamic filling-in process dependent on visual motion that facilitates filling-in of spatiotemporal visual structure and works even if there is no stimulation at the opposite blind spot boundary.

62.16, *12:00 pm* **A squishiness visual aftereffect – Not causality adaptation** Derek Arnold[1](darnold@psy.uq.edu.au), Kirstie Petrie[1], Regan Gallagher[1], Kielan Yarrow[2]; [1]Perception Lab: School of Psychology, The University of Queensland, [2]Department of Psychology, City University London

Imagine viewing a simulated collision – a disc moves until it just touches another disc, at which point the first disc stops still and the second launches into motion. After repeated viewings of this scenario (visual adaptation), if people are shown a display wherein the first disc moves until it is partially occluded by the second, they are less likely to report that the first disc had launched the second into motion [1]. This has been interpreted in terms of a visual adaptation of causality perception . We reasoned that another interpretation was plausible. Instead of a direct visual adaptation of causality, these data could be indicative of a perceptual aftereffect impacting anticipated elasticity, or squishiness. Repeated viewings of the adaptation contact-launch scenario might induce a perceptual expectation that the two discs are rigid (as the initially static disc starts moving as soon as contact is made), and so a partial occlusion would become a strong cue that the two discs have not collided. If, instead, people repeatedly watch the first disc becoming partially occluded by the second before launch, they might form the impression that the two discs are squishy, and become more likely to report 'launches' in similar circumstances. We found support for this premise. Moreover, we found that the same adaptation protocol could bias judgments of a non-causal relationship, namely categorisations of simulated bounces as being hard (like a pool ball bouncing on concrete) or soft (like a squash ball bouncing). 1. Rolfs, M., Dambacher, M. & Cavanagh, P. (2013). Visual adaptation of the perception of causality. Current Biology, 23, 250-254.

Acknowledgement: The Australian Research Council

62.17, *12:15 pm* **Apparent speed of a rotating disk varies with texture density** Stuart Anstis[1](sanstis@ucsd.edu), Alan Ho[2]; [1]UC San Diego, 9500 Gilman Drive, La Jolla CA 92093-0109, [2]Ambrose University College, Calgary AB T3H 0L5, Canada

A circle of white dots on a black surround was made to rotate on different trials at speeds ranging from 5.6°/s to 360°/s (= 0.016 to 1 rev/min). We found, by a matching method, that the apparent speed of rotation increased as the number of dots increased. Result: when compared across all speeds with a circle of eight dots, four dots appeared to rotate 16% more slowly, and sixteen dots appeared to rotate 33% faster. Same results were found for second-order random-texture dots that rotated on a background of the same texture. (However, if 16 dots were alternately 8 black and 8 white dots on a grey surround, their apparent speed was the same as for 8 dots.) Both spatial and temporal factors played a part in this illusion. Speed = Distance/Time, or equivalently, for a drifting grating, Speed = Temporal frequency/Spatial frequency. So dots spaced far apart round a circle had a long spatial period (equivalent to low spatial frequency for a grating), and perceived speed was judged partly as the time for an object to move through its own diameter, so four far-apart dots seemed to move more slowly than 16 close-together dots (JF Brown 1927, 1931). Also, sixteen dots moving past a fixed point had 4 times the temporal frequency of four such dots, which contributed to their appearing to move faster.

Attention: Temporal

Wednesday, May 21, 10:45 am - 12:30 pm
Talk Session, Talk Room 2
Moderator: Trafton Drew

62.21, *10:45 am* **A magnocellular contribution to conscious object perception via temporal object segmentation** Stephanie C. Goodhew[1](s.c.goodhew@gmail.com), Hannah L. Boal[1], Mark Edwards[1]; [1]Research School of Psychology, The Australian National University

The human visual system is continuously confronted with dynamic input. One problem that the system must solve, therefore, is recognising when two distinct objects have appeared at a given location despite their brief presentation and rapid succession (temporal object segmentation). Given the superior temporal sensitivity and faster conduction speeds of magnocellular neurons relative to parvocellular neurons, here we examined the role of magnocellular neurons in temporal object segmentation. We measured temporal object segmentation via object substitution masking (OSM), which reflects the failure to distinguish the target and mask as distinct objects through time (see Goodhew et al., 2013, PBR, for a review). Specifically, participants' task was to identify the location of the gap in a target Landolt C surrounded by four-dots when the target and four-dots disappeared simultaneously (simultaneous mask offset, unmasked control) or when the four-dots temporally-trailed after target offset (delayed mask offset, masked condition). We isolated the selective role of magnocellular neurons by comparing target identification performance under conditions of pulsed versus steady luminance pedestals. A pulsed pedestal is designed to saturate the magnocellular response with a rapid pulse of luminance concurrent with the target array, whereas a steady-pedestal condition leaves both the magnocellular and parvocellular channels available to process the target (Pokorny, 2011, JOV). Across two experiments, we found that OSM magnitude was selectively enhanced under pulsed pedestal conditions, despite the fact that the pulsed pedestal did not alter overall target identification accuracy. This indicates that magnocellular neurons underlie our ability to resolve and consciously perceive two distinct objects despite their close spatiotemporal proximity. Given that this process of temporal object segmentation has consequences for which stimuli are consciously perceived, this demonstrates a functional role via which magnocellular neurons contribute to determining the contents conscious perception.

62.22, *11:00 am* **No action video game training effects for flicker change detection** Amyeo Jereen[1](ajereen@wellesley.edu), Anika Guha[1], Joseph DeGutis[2], Jeremy Wilmer[1]; [1]Wellesley College, [2]Boston VA

The frustrating experience of a good flicker change detection (FCD) task beautifully demonstrates a cognitive capacity more limited than we feel it should be. Yet some individuals have a far greater capacity to notice such changes than others. What is the source of these differences, and can cognitive training enhance our FCD ability? A recent report of superior FCD performance in action video game players raises the possibility that playing such games may improve FCD ability (Clark, Fleck & Mitroff, 2011). We conducted a randomized, controlled trial (n=81, 12 hours of training) to see if action video game play would enhance FCD ability. Our game of interest was Medal of Honor (MOH), a first-person shooter used in many prior action video game training studies (e.g. Green & Bavelier, 2003). Our two control games were World of Goo (WOG, a strategy game) and Wii Sports (WS, a sports game), and we included a no-training control condition (NTC). To sensitively detect potential training-related improvements, we used a highly reliable FCD task (alpha=0.88). An extensive post-training questionnaire confirmed that participants were blind to our hypothesis. While all conditions improved significantly ($p<0.01$), improvement did not differ significantly between conditions ($F(3,75)=0.76$, $p=0.52$). Improvement in the MOH condition was numerically (though not significantly) lower than that of the WOG condition, suggesting no hint of a differential training effect for MOH. Furthermore, no single training condition improved significantly more than the NTC condition, strong evidence against even a non-specific improvement for all video games. In sum, action video game playing did not improve FCD ability in our study. These results, in combination with our prior finding of high heritability of FCD ability (Wilmer et al, 2012), suggest that FCD may be relatively impervious to environmental factors.

Acknowledgement: Brachman Hoffman Fellowship to JW

62.23, *11:15 am* **Entraining or Awakening: Perceptual Consequences of Visual Stimulation** Jess R. Kerlin[1](KerlinJR@bham.ac.uk), Jane E. Raymond[1], Simon Hanslmayr[1], Kimron L. Shapiro[1]; [1]School of Psychology, University of Birmingham, U.K.

Recent studies report that rapid serial visual presentation (RSVP) of task-irrelevant stimuli can have significant consequences for the perception of subsequent visual targets. One explanation for this effect is that rhythmic presentation of visual objects entrains visual cortex into a phase-locked oscillatory rhythm, resulting in rapid cycles of enhanced and suppressed perception. An alternative view is that rapid visual presentation leads to rhythm-independent neural state changes in the visual system, with enhancement of processing due to a combination of stochastic resonance ("cortical awakening") and competition incited by task-irrelevant stimuli. We sought to distinguish between these theories through a series of RSVP experiments measuring single target identification. In Experiments 1 and 2, trains of task-irrelevant black letters were presented at six frequencies between 3.3 and 36 Hz, in and out-of-phase, with a final, backward-masked red target letter. Both in and out-of-phase stimulation versus a control condition facilitated 6AFC forced-choice target identification. In Experiments 3-5, task-irrelevant letters or noise patterns were presented rhythmically and non-rhythmically at 10 Hz, followed by a red target 100 ms later ("in-phase"). In every condition, stimulation resulted in improved performance compared to a control condition, with no significant differences between the rhythmic and non-rhythmic conditions. Finally, Experiment 6 tested a full range of non-harmonic RSVP frequencies and final distractor-to-target asynchrony (DTA) in a 5x5 orthogonal design (n = 80). Stimulation at frequencies 10 Hz and above led to better performance, with poorer performance at DTAs of 35 and 167 ms. No interaction between frequency and DTA was found. The current results are consistent with models of awakening and competition, but inconsistent with oscillatory entrainment models. Perceptual consequences of rapid, task-irrelevant visual stimulation appear to be determined by a combination of "awakening" of the visual system and previously known competition arising from distractors.

62.24, *11:30 am* **Visual extinction in Parkinson patients** Sara Agosta[1](sara.agosta@iit.it), Raffaella Di Giacopo[2], Lorella Battelli[1,3]; [1]Center for Neuroscience and Cognitive Systems@UniTn, Istituto Italiano di Tecnologia, Rovereto, Italy, [2]CeRiN, Neurocognitive Rehabilitation Center, Center for Mind/Brain Sciences, University of Trento, Rovereto, Italy, [3]Berenson-Allen Center for Noninvasive Brain Stimulation and Department of Neurology, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, Massachusetts, USA

Parkison's disease (PD) has been described as a disconnection syndrome. Motor and non-motor symptoms of PD have been explained as a consequence of the disconnection in the cortico-striatal-thalamocortical and cortico-cortical circuitry. The motor onset of PD symptoms, on the right or on the left side of the body, indicate an asymmetrical dysregulation of the dopamine depletion in the substantia nigra and consequently in the striatum and, in turn, dysfunction of basal ganglia and connected cortical areas. For this reason, it is important to determine whether the timecourse of the motor impairment on one side is also correlated with non-motor cognitive impairments more often documented for one specific hemisphere. Interestingly, there is some experimental evidence that left PD patients (LPD, primarily with right hemisphere degeneration) show visuo-spatial deficits similar to patients affected by right parietal lesion (Cronin-Golomb, 2010). We tested a group of PD patients at various stages of the disease on a sustained attention task, namely a multiple object tracking (Battelli et al., 2001). This task is particularly sensitive at revealing signs of left visual extinction in right parietal patients. PD patients were asked to track 4 moving discs amidst moving distracters (8 total discs, four in each hemifield) two in the left and two in the right hemifield. We psychophysically measured left and right visual field tracking speed thresholds at which patients could perform at 80% accuracy. Results showed a double dissociation, LPD patients showed an impaired performance (relative to age-matched controls) in the left hemifield, while right PD patients showed lower thresholds in the right hemifield. This dissociation indicates that PD is a degenerative disease involving motor as well as attentional functions both in the early and late stage of the disease. This results also critically link sustained attention to cortical-basal ganglia connections.

62.25, *11:45 pm* **Re-examining temporal selection errors during the attentional blink** Patrick T. Goodbourn[1](patrick.goodbourn@sydney.edu.au), Paolo Martini[2], Michael Barnett-Cowan[3,4], Irina M. Harris[1], Evan J. Livesey[1], Alex O. Holcombe[1]; [1]School of Psychology, University of Sydney, Australia, [2]Department of Psychology, University of Warwick, United Kingdom, [3]Department of Psychology, University of Western Ontario, Canada, [4]Department of Kinesiology, University of Waterloo, Canada

Two attentional episodes cannot occur very close in time. This is the traditional theory of the attentional blink, and it correctly predicts that the second of two successive attentional episodes often fails. But even when an episode succeeds, it may occur at an inappropriate time. Based on an analysis of response errors, Vul, Nieuwenstein and Kanwisher (2008) concluded that selection associated with a second target (T2) was temporally advanced for short lags and delayed for longer lags, and was less temporally precise during the blink period. However, their parametric estimates of attentional episode characteristics can be biased by instances in which the item reported for T2 was selected during an episode directed at the first target (T1). Such instances are evident in response error distributions, and could explain the phenomenon of lag-1 sparing. We reanalysed data from six studies, using mixture modelling to assess the characteristics of attentional episodes. At each lag, we compared two models: the first assumed that both target reports (T1 and T2) were drawn from a single attentional episode directed at T1; the second included an additional episode directed at T2. The results suggest that a second episode occurs only if lag exceeds 100–250 ms, with the probability of initiating an episode returning to baseline for lags beyond about 500 ms. When a second episode does occur, the magnitude of its delay decreases as lag increases; but its temporal precision is invariant with lag, and is indistinguishable from a T1 baseline. This confirms that second attentional episodes are suppressed and delayed, but suggests that they are not temporally advanced for short lags, and that their temporal precision is not affected by earlier episodes. It also suggests that at least two items are sometimes retrieved from the first attentional episode, explaining lag-1 sparing.

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62.26, *12:00 pm* **Shuffling your way out of change blindness** Trafton Drew[1,2](traftondrew@gmail.com), Jeremy M. Wolfe[1,2]; [1]Brigham and Women's Hospital, [2]Harvard Medical School

The ability to identify differences between two images is an important task in a variety of real world settings. For instance, in diagnosing cancer, radiologists may compare a patient's prior and current images to determine whether an innocuous blip has grown into a malignant mass. This process is typically performed by displaying the two images side by side (SbS) and looking back and forth between the images. In settings like astronomy, it is much more effective to toggle between two images in the same location on the screen. However, while it is easy to take two identical pictures of the night sky to look for a planet, it is impossible to take two identical mammomgrams 6 months apart. Would this method, dubbed "shuffling", improve performance, even with imperfect alignment of the images? We created pairs of real world pictures where one object had been moved on half of the photos. Each image set was randomly viewed in either SbS or Shuffle condition. In Experiment 1, observers had a time limit. The percentage of changes detected was higher in Shuffle (57%) views than in SbS views (50%, $t(22)=2.6, p<.03$, cohen's $d=.4$). In Experiment 2, the time limit was removed. There was no longer a benefit in hit rate, but observers were markedly faster in the Shuffle (19s) than in the SbS condition (25s, $t(22)=6.1, p<.001$, cohen's $d=.8$). An eye-tracking follow up experiment replicated the speed benefit of the shuffle view and suggested that the benefit was primarily due to decreased decision time in the Shuffle condition: once a target had been fixated, observers in the Shuffle condition tended to take substantially less time (~6s) to identify it as a target. Shuffling is not a 'cure' for change blindness but the benefit may be large enough to have impact on some radiology exams.

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62.27, *12:15 am* **Pure Irrelevance Induced 'Blindness'** Yaffa Yeshurun[1](yeshurun@research.haifa.ac.il), Roy Shoval[1], Baruch Eitam[1]; [1]Psychology Department, University of Haifa

This study examined whether relevance per-se can cause blindness (i.e., failure to report clearly visible stimuli) even when there is no resources limitation. In a novel paradigm, employed in 2 similar experiments, a colored circle surrounded by a differently colored ring was presented for 500 ms, without masking. One of these stimuli was labelled as relevant at the beginning of the trial. Following the stimuli offset, the observers were asked to identify the colors of both relevant and irrelevant stimuli (report order was counterbalanced). While color identification of the relevant stimulus was near perfect, up to a quarter of the participants could not name the color of the irrelevant stimulus. Critically, a control experiment indicated that there were sufficient resources to process both stimuli. The fact that the effect of relevance was similar regardless of whether the observers had to report the irrelevant stimulus first or second suggests that this blindness does not reflect forgetting. Instead, we propose that our observers were aware of the irrelevant color when it was displayed, but due to irrelevance, its representation was insufficiently activated, resulting in recognition failure. To explore this possibility we run another experiment in which an illusory rectangle was created via modal-completion brought about by 4 colored inducers. Previous studies suggest that such modal-completion can only take place with conscious inducers. Task instructions only required identification of the rectangle orientation, but following the inducers offset the observers were also asked to report the inducers color. Like before, reports of rectangle orientation (relevant stimulus) were highly accurate (though here the order did matter), suggesting that the irrelevant inducers reached awareness, yet reporting their color often failed. Overall, these results demonstrate blindness when mental resources are clearly available, challenging attentional theories that predict strong selection only when resources are taxed.

Wednesday Morning Posters

Perception and action: Locomotion, wayfinding, space

Wednesday, May 21, 8:30 am - 12:30 pm
Poster Session, Jacaranda Hall

63.301 Effects of discrepant optic flow during walking on the perceived visual and proprioceptive straight ahead in egocentric space

Jing Chen[1](chenjingpku@gmail.com), Kang He[2], KunLin Wei[2], Li Li[1]; [1]Department of Psychology, The University of Hong Kong, Hong Kong SAR, [2]Department of Psychology, Peking University, China

Previous research has shown that discrepant optic flow experienced during walking with prism glasses can shift both the visual and proprioceptive straight ahead (SA) in egocentric space. Here by having participants walk in an immersive virtual environment, we examined how adding optic flow information in the scene affected such shifts and whether such shifts increased with prolonged exposure to discrepant optic flow. Nineteen participants wore a head-mounted display (44°Hx34°V) and walked toward a red post target placed on a textured ground or a doorway on the back wall of a room. The target and the doorway were both at 8 m. The room display provided denser flow and motion parallax information than did the textured ground display. Participants' visual heading specified by optic flow was displaced by ±10° from their physical walking direction, causing discrepant optic flow. We measured participants' VSA and PSA before walking, after 10 trials, 20 trials, and 30 trials of walking, respectively. For VSA measurement, the experimenter moved a light spot on a wall and participants judged when it was at their SA. For the PSA measurement, participants were blindfolded and used a laser pointer to point at their SA. We found a significant shift in PSA for both the room and the textured ground displays. The shift in PSA was larger than that in VSA for both displays, and the shift in VSA was significant for the room (about 2°) but not the textured ground display. The shifts in both PSA and VSA increased with the number of trials tested for the room but not the textured ground display. We conclude that discrepant optic flow during walking recalibrates PSA in egocentric space more than VSA, and this recalibration increases with the exposure to discrepant optic flow when the display contains rich optic flow information.

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63.302 The structure of spatial knowledge: Do humans learn the geometry, topology, or stable properties of the environment?

Jonathan Ericson[1](jonathan_ericson@brown.edu), William Warren[1]; [1]Brown University

The present experiments tested three hypotheses about the structure of spatial knowledge used for navigation: the Euclidean, Topological, and Stability Hypotheses. We selectively destabilized three geometric properties of the environment during learning: metric, neighborhood, or graph structure. If spatial knowledge is primarily Euclidean, performance on all tasks should deteriorate when metric structure is destabilized; if spatial knowledge is primarily topological, performance should reflect the graph when metric and neighborhood structure are destabilized; if navigators acquire whatever geometric properties are stable during learning, performance should reflect the stable structure in each environment. Method. During learning, 10 groups of participants (N=120) walked in one of four virtual hedge mazes containing 10 target objects: (1) The Control Maze preserved all three properties. (2) Elastic Maze I preserved the place graph but destabilized Euclidean and neighborhood structure by stretching some hallways across neighborhood boundaries 50% of the time. Metric information (from path integration) but not visual information for these boundaries was available. (3) Elastic Maze II added visual information for these neighborhood boundaries. (4) The Swap Maze preserved neighborhoods but destabilized Euclidean and graph structure by swapping certain object locations 50% of the time. In the test phase, spatial knowledge was probed in one of three navigation tasks: (a) metric shortcut task, to assess Euclidean knowledge, (b) neighborhood shortcut task, to assess knowledge of neighborhoods, (c) route task, to assess graph knowledge. Results are inconsistent with Euclidean and Stability hypotheses, but support the Topological hypothesis. Metric shortcuts are highly unreliable (Angular Deviations ~24° in Control maze) and neighborhood shortcuts suffer even when neighborhoods are stable (21.4% incorrect in Swap maze). But the place graph is learned in all environments (96% accuracy on route task). Spatial knowledge appears to be primarily topological, consistent with a labeled graph that incorporates approximate local distances and angles.

63.303 Effect of spatial or sequential auditory secondary task on spatial navigation

Wendy Baccus[1](wbaccus@gmu.edu), Sarah Dziura[1], Jacob Bevitt[1], James Thompson[1]; [1]George Mason University

Human navigation relies on numerous cognitive operations, including location representation and route sequence memory. Using a memory of the spatial layout of locations and landmarks to guide behavior might be expected to draw heavily on spatial working memory (WM), whereas it has been suggested that route-based navigation draws upon a sequential memory representation. In previous work we have shown individual differences in the tendency to use these two navigational strategies. In the present study, we examined the contribution of working memory for spatial layout or a sequence on navigation, using a concurrent secondary task as participants navigated though a virtual environment. Participants (n = 60) learned to navigate from a start location to a target using a fixed route, and were then placed at a different location and asked to navigate to the previously learned target. During these probe recall trials, participants were randomly assigned to concurrently perform an auditory spatial WM task, an auditory sequence WM task, or a control task. We divided participants into those utilizing either a sequence-based or spatial-based strategy according to target marking with respect to the trained route or spatial layout of the environment. Spatial-based participants were differentially impacted by both secondary tasks; concurrent sequence WM led participants to consistently misplace the target location by a small but significant margin, whereas concurrent spatial WM significantly increased between-subject variability of target location. Notably, sequence-based participants were not disrupted by either secondary task. These results suggest that sequence-based memory is easier to maintain during any secondary task, while spatial-based memory is sensitive to interference from both spatial and sequence WM tasks. However, based on the degree of target mislocation, the attentional requirement of a concurrent spatial WM task has a greater impact on spatial-based navigational strategies than a sequential WM task.

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63.304 Effect of attentional load on visual control of steering toward a goal

Rongrong Chen[1](rainerrchen@gmail.com), Li Li[1]; [1]Department of Psychology, The University of Hong Kong, Hong Kong SAR

While walking and driving in heavy traffic in daily life requires paying attention to other surrounding moving objects, how simultaneously performing an attention demanding task affects the visual control of goal-directed steering remains unknown. Here we examined how different attentional loads affected people's steering toward a goal at both low and high travel speeds. The display (113°H×88°V) simulated a participant traveling at a walking speed of 2 m/s or a driving speed of 15 m/s over a texture ground for 10 s. Participants used a joystick to control the curvature of their traveling path to steer toward a red post target. Concurrently, participants visually tracked one dot (low attentional load) or three dots (high attentional load) among eight dots that randomly moved inside a red circle (radius 3.5°) on top of the target post. Participants' virtual heading had a constant 10° offset from their straight ahead such that steering to center the target at straight ahead would result in a constant 10° heading error. Across nine participants, while the tracking accuracy of low attentional load was not affected by travel speed, the tracking accuracy of high attentional load decreased from 84%±2% (mean±SE) to 74%±1% as travel speed increased from 2 m/s to 15 m/s. For the steering performance in the trials with accurate tracking response, peak path curvature decreased and mean heading error averaged across the first 4-s steering increased with attentional load at both travel speeds. However, after 4-s steering, heading error converged to participants' optimal performance at each travel speed and was not affected by the attentional load. We conclude that participants have more difficulty in dealing with high attention demanding task at high than low travel speed. Attentional load affects the early stage of steering control but does not affect the final heading error.

Acknowledgement: Hong Kong Research Grant Council, HKU 7480/10H and 7482/12H

63.305 **The visual influence on path reproduction in darkness is stronger during childhood** Karin Petrini[1](k.petrini@ucl.ac.uk), Andrea Caradonna[2], Celia Foster[3], Neil Burgess[4], Marko Nardini[5]; [1]UCL Institute of Ophthalmology, Department of Visual Neuroscience, UK, [2]UCL Research Department of Neuroscience, Physiology and Pharmacology, UK, [3]UCL Division of Biosciences, UK, [4]UCL Institute of Cognitive Neuroscience and University College London Institute of Neurology, UK, [5]Department of Psychology, Durham University and UCL Institute of Ophthalmology, Department of Visual Neuroscience, UK

Studying how we retrace our way in darkness provides a means of understanding the internal representations we use during navigation. In adults, path integration in darkness is influenced by previously presented visual information that conflicted with actual motion (Tcheang et al, PNAS, 2011, 108(3): 1152-7). Here we used immersive virtual reality to isolate visual and motor cues during encoding of a path in children and adults, and examined whether the cues' relative contributions to the stored path representation reflect optimal integration. Eighteen adults and fifteen 10-11-year-old children were guided along a two-leg path in darkness (motor-only), in a virtual room (visual-motor), or they watched a pre-recorded walk in the virtual room while standing still (visual-only). Participants then reproduced the path in darkness. By fitting bivariate normal distributions we obtained a measure of the dispersion of the end-points (variable error) and of their distances from the correct end point (constant error). While adults performed similarly across all three conditions, 10-11-year-old children reduced their variable error when encoding in the bimodal condition, indicating integration of cues. Both adults and children showed greater constant error in the visual-only condition than the motor-only (although significantly greater in adults than children), while the constant error for the visual-motor was intermediate between these two. A significant inverse correlation between visual-motor constant error and number of trials indicated that with only 10 repetitions children learnt to better combine the two cues. These results indicate that 10-11 year-old children can learn to optimally combine visual and motor information to encode a path. Adults' inability to do this could reflect their complete reliance on internal motion-related information because of its greater perceived reliability and relevance to the task. This suggests that the representations we use to navigate in darkness change significantly during the lifespan.

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63.306 **Event file activation interferes allocation of visual attention during motor movement** Kazuhiko Yokosawa[1](yokosawa@l.u-tokyo.ac.jp), Marie Shoda[1]; [1]The University of Tokyo

Visual attention was oriented toward the kinematic movement's direction (Deuel et al., 1998). Event coding theory (ECT; Hommel, et al., 2001) assumes the motor and perceptual systems are bilaterally linked, mediated by an integrative coding system: event file. It remains unclear whether the activation of event file affects visual attention directly during kinematic movement. This study examines whether the activation of event file affects the allocation of visual attention, while conducting kinematic movement. Specifically, the difficulty of orienting visual attention is compared for actions of treadmill walking, stepping-in-place and standing. Kinematic movement was similar between treadmill walking and stepping-in-place, though body gravity moves forwardly only during treadmill walking, therefore its kinematic movement was more salient. We conducted an experiment in the dark room to eliminate optic flow, which could stimulate locomotion. As a cognitive task, Posner paradigm was used to examine the covert allocation of visual attention, based on the exogenous visual cue, which denoted target location. Participants had to identify a target (X/O), preceded by the cue. Cue validity was 50% over three conditions: valid, horizontal invalid and vertical invalid. In the horizontal invalid condition cue and target appeared at symmetrically opposite locations about the vertical axis; in invalid vertical condition they appeared on opposite sides about the horizontal axis. Significant cuing effects emerged regardless of locomotion conditions. Relative to the standing condition, accuracy rose significantly during treadmill walking in the horizontal invalid condition. These results showed that treadmill walking made it difficult to allocate the visual attention in the horizontal direction. Therefore the activation of event file affected visual attention, without any interference in visual system. We suggest that treadmill walking enhances the vertical code of event file thereafter this enhancement asymmetrically disrupts the allocation of visual attention along horizontal axis.

63.307 **A data-driven approach to learning strategies for the visual control of navigation.** Youssef Barhomi[1](youssef.barhomi@gmail.com), Abigail Yanke[1], Stephane Bonneaud[1], William Warren[1], Thomas Serre[1]; [1]Department of Cognitive, Linguistics, and Psychological Sciences, Brown University

Rapid visual presentation paradigms, characterized by short presentation times and speeded behavioral responses, have played a central role in the study of our core visual recognition ability. Here, we adapted the rapid presentation paradigm for a visual navigation task to study how pre-attentive vision controls behavior. Method. We used CryEngine, a state-of-the-art gaming engine, to synthesize videos simulating self-motion through naturalistic scenes from a first-person view at a human walking speed (~1.4m/sec). Modern gaming engines offer the possibility to create relatively controlled, yet realistic, visual environments. Participants were presented with these 300ms long masked video sequences and used the mouse to report their preferred best direction to steer in order to navigate through the scene while avoiding obstacles. The best steering direction was selected from a continuum indicated by arrows along a circle projected on the ground. Participants were instructed to answer as accurately and as fast as possible to limit cortical feedback. Results. We computed a navigability index for each video by computing the proportion of responses from all participants in each steering direction (18 bins of 10 deg azimuth). Overall we found a high degree of consistency across participants, suggesting that they understood the task and relied on similar scene information. Behavioral data were consistent with steering directions predicted by a model for the behavioral dynamics of steering (Fajen & Warren, 2003) based on ground-truth depth data. We further used the behavioral responses to evaluate a variety of visual cues, from motion and shape to saliency, and to learn to predict participants' steering directions. Overall, the relative success of the proposed approach suggests that it may be possible to learn visual strategies (e.g. visual equalization, saccade and clutter response, etc.) directly from data without explicitly implementing them.

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63.308 **Inverted vection as a function of vection strength induced by background motion** Yasuhiko Saito[1](saitoy@psyche.mind.tohoku-gakuin.ac.jp), Kenzo Sakurai[2]; [1]Tohoku Gakuin University Graduate School, [2]Tohoku Gakuin University

Nakamura and Shimojo (2000) reported inverted vection, illusory self-motion perception in the same direction as a foreground motion, induced by a combination of the slowly moving foreground and an orthogonally fast moving background. They also claimed that inverted vection occurred when the orientation of the self was destabilized by the motion of the background (Nakamura & Shimojo, 2003). If that were the case, inverted vection strength would increase as a function of the strength of vection induced by the moving background. We conducted 2 experiments to test this possibility by varying the velocity of moving random-dots of the background (experiment 1) and their motion direction coherence (experiment 2). Observers wore a shutter goggle and viewed stereoscopic stimuli, i.e, the background pattern 15cm farther and the expanding/contracting random-dots foreground pattern 15cm nearer than the screen. Observers reported the perceived self-motion duration and its direction (rightward/leftward or forward/backward) by pressing one of the 4 response keys, each for vection by background and for inverted vection by foreground. In experiment 1, 6 velocities (1, 5, 10, 15, 20, 25 deg/sec) for each direction were applied to random-dots' horizontal motion of the background. Results showed that the total duration of vection increased from 1 to 10 deg/sec then saturated up to 25 deg/sec, while the total duration of inverted vection increased as the velocity was higher than 10 deg/sec. In experiment 2, 11 coherence values (0 ~ 100% in 10% step) were applied to random-dots' motion direction of the background. Results showed that the total duration of vection increased from 0 to 50 % then saturated up to 100%, while the total duration of inverted vection increased as the coherence was higher than 50%. These results support Nakamura & Shimojo's claim that inverted vection occurs when the orientation of the self is destabilized.

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63.309 Decoupling the Biomechanics of Locomotion and the Direction of Spatial Updating During Blind-Walking Tasks Adam J. Barnas[1](barnasa1@udayton.edu), Benjamin R. Kunz[1]; [1]University of Dayton

In order to guide whole-body movements in the absence of visual feedback, one must dynamically update position as a function of movement. This process of spatial updating is thought to be automatic, and likely underlies accurate performance in tasks that involve blind-walking to goal locations. Walking to previously-viewed targets is accurate when the direction of spatial updating and direction of movement are consistent (Paquet et al., 2007). When biomechanical information is absent, as in imagined walking without overt movement, walking times are significantly underestimated compared to real walking times (Kunz et al., 2009). We further investigated the role of biomechanical information in spatial updating by decoupling the direction of locomotion and spatial updating in backward blind-walking. In a baseline experiment, participants viewed targets directly in front of or behind them and walked either forward or backward without vision to the targets while spatially updating in a manner consistent with their direction of movement. Participants were generally accurate in both forward and backward blind-walking, suggesting that participants spatially update in a manner consistent with their direction of movement, even for less common forms of locomotion, such as backward walking. In subsequent experiments, targets were always placed in front of participants. Participants either spatially updated while walking forward without vision to targets or walked backward away from targets while spatially updating in a manner consistent with forward walking, thereby spatially updating in a direction opposite their direction of movement. The accuracy of backward walking decreased when the biomechanics of locomotion were inconsistent with the direction of spatial updating. The results are consistent with previous findings that illustrate automatic spatial updating when walking without vision; spatial updating is less automatic and more effortful when there is a mismatch between the direction of locomotion and the direction of spatial updating.

63.310 Intercepting a moving target in fog: On-line or model-based control? Huaiyong Zhao[1](huaiyong_zhao@brown.edu), William Warren[1]; [1]Department of Cognitive, Linguistic and Psychological Sciences, Brown University

When walking to intercept a moving target, people appear to use a constant bearing strategy (Chardenon, et al., 2002, 2005; Lenoir, et al., 1999, 2002): interception behavior is closely modeled by nulling change in the bearing direction of the target, based on current visual information (Fajen & Warren 2004, 2007). Alternatively, interception might be controlled by an internal model of the target's motion, which is updated by current information (Diaz, et al., 2013). To investigate whether interception is under on-line or model-based control, participants intercepted a moving target that became visually blurred or totally occluded, as if in fog. Participants (N=10) walked in a virtual environment (12m x 12m), and displays were presented stereoscopically in a head mounted display (63°H x 53°V, 60 Hz), while head position was tracked (60 Hz). The target (7.8m distant) moved at 0.6, 0.8 or 1.0 m/s. 2.5s after it appeared, the target either remained fully visible or passed behind a translucent gray occluder, so it was blurred at one of 4 levels or completely occluded; 2.5-6.0s later the participant reached the occluder and their position was recorded. Blur levels were created by varying the target's width and contrast using a Gaussian filter, to induce position and speed uncertainty. As blur increased, participants increasingly lagged behind the target ($p<0.01$) and SD of this error increased ($p<0.01$), with total occlusion yielding the largest errors (CE=-1.0m, mean SD=0.4m, $p<0.01$). Thus, degrading target visibility progressively impairs interception accuracy and precision, and occlusion severely impairs performance. The results are consistent with dependence on current visual information, and imply that the fidelity of an internal model, if one exists, rapidly decays beyond the greatest blur level and is ineffective for guiding locomotion. These findings suggest that interception of a moving target is normally controlled on-line based on current visual information.

63.311 Memorizing slope but not elevation facilitates navigation in a virtual environment Hiroyuki Tsuda[1](tsudahiroyuqi@gmail.com), Jun Saiki[1]; [1]Graduate School of Human and Environmental Studies, Kyoto University

Previous research indicates that environments with slopes and slanted terrain have the potential to provide several kinds of additional spatial cues, leading to improved navigational performance. However, what kind of cue is most important for that facilitation remains unclear and what types of memory representations are formed and successfully used in navigation is largely unknown. There could be at least two types of memory representation that can be used for navigation in environments with undulating terrain: global elevation knowledge and local memory of slopes. In the current experiment, we investigated which type of memory representation (elevation vs. slope) is useful in learning to navigate in a virtual environment by identifying correlation between memory performance and successful navigation. The experiment was conducted in a virtual environment with undulating terrain which contained eight landmarks connected with navigable streets. The experiment consisted of a learning phase followed by a navigation task and two memory tasks. In the learning phase, arrows were placed at the road junctions directing participants and they followed the route to learn the layout of the environment. In navigation task, participants performed a sequence of eight successive navigation trials and each navigation duration to reach the goal were measured. In elevation memory task, knowledge about the relative elevation of places in relation to each other were measured. In slope memory task, participants recalled the direction of each local slopes. We found no correlations between navigation duration and memory performance. However, when data were separately analysed according to participants' sense of direction (SOD) scores, high SOD group revealed a significant correlation between navigation and slope memory. This suggests that local scene memory of slopes are more useful than elevation knowledge in navigation, but only participants with high SOD can successfully utilize it.

63.312 Visual coupling to multiple neighbors in a crowd influences walking speed and direction Kevin W. Rio[1](kevin_rio@brown.edu), William H. Warren, Jr.[1]; [1]Dept. of Cognitive, Linguistic, and Psychological Sciences, Brown University

Pedestrians in a crowd are visually coupled to nearby neighbors, yielding a common speed and direction of travel (heading). Previously, we derived a visual control law for walking together with one neighbor (Rio & Warren, VSS 2011; Page & Warren, VSS 2013). Here, we extend this framework to investigate how multiple neighbors combine to influence a pedestrian. We collected data from a participant (N=10) walking with 3 confederates in a diamond configuration across a 12x14m room, while recording head position with an ultrasonic tracking system. On some trials, confederates received covert instructions to change their direction (turn left, turn right) or speed (speed up, slow down), and the effect on participant's final lateral position or speed, respectively, was measured. The number of manipulated confederates (1, 2, or 3), their positions (left, center, right), and their initial distance from the participant (1 or 2 m) were varied. For both direction and speed manipulations, there was a main effect of the number of confederates manipulated (direction: $F(8,64)=20.17$, $p<0.001$; speed: $F(8,64)=2.29$, $p<0.05$), with more confederates eliciting larger participant responses. For the speed manipulation, there was also a main effect of neighbor distance ($F(8,64)=2.29$, $p<0.05$), although this was not the case for direction ($F(1,8)=0.033$, $p>0.05$). Multiple linear regression on participants' final position reveals that the confederate directly ahead [center] is weighted more heavily than confederates to the left or right (Beta=0.32, 0.17, 0.26, respectively; $R2=0.47$); the same holds for multiple regression on participant speed (Beta=0.40, 0.26, 0.20, respectively; $R2 = 0.46$). The results indicate that the influences of multiple neighbors are linearly combined, weighted by their position and, in the case of speed, their distance. We extend our previous control law to model this multiple visual coupling, which may be applied in simulations of human crowd behavior.

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63.313 Visual control strategies for stepping over obstacles Melissa Parade[1](melissa.parade@gmail.com), Brett Fajen[1]; [1]Rensselaer Polytechnic Institute

The aim of this study was to investigate the visual control strategies that walkers use to step over obstacles, with a specific focus on how the adopted strategy allows walkers to accommodate variations in obstacle height and depth. Subjects walked through a virtual environment viewed through a head-mounted display while their lower body was tracked by a motion capture system. They walked from a home position to a goal while stepping over a virtual obstacle, the height and depth of which were manipulated as independent variables. We found that adaptations to variations in obstacle dimension began during the step by the trailing foot to its location in front of the obstacle. Subjects adapted to deeper obstacles by planting their trailing foot closer to the obstacle, which allowed the leading foot to reach peak elevation closer to the intended landing location behind the obstacle. However, planting the trailing foot closer to the obstacle means that it must be elevated more quickly as it moves forward to clear deeper obstacles. The trailing foot must be elevated more quickly to clear taller obstacles as well. To maintain stability and forward progress while quickly elevating the trailing foot, walkers could lean the upper body forward toward the end of the leading foot's step over deeper and taller obstacles, and then let the upper body return to equilibrium as the trail-

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ing foot is rapidly lifted to clear the obstacle. This is consistent with an observed decrease in head velocity while the trailing foot crosses the obstacle. We test this hypothesis in a follow-up experiment in which walkers step over different sized obstacles with their right and left feet. The findings suggest that visual information about obstacle dimension is used to modulate stepping behavior as early as the last step before the obstacle.

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63.314 The relationship between low-level visual tasks and steering control

Bobby Nguyen[1](bhnguyen@wichita.edu), Rui Ni[2]; [1]Psychology Department, Wichita State University

Integrating visual information spatially and temporally is important in motion perception and steering in a driving task. Our recent research showed that reduced optic flow quality and quantity impaired steering performance under reduced visibility conditions. However, it is not clear how the spatial and temporal integration of visual information affects steering control under these conditions. In the current study we examined the effect of low visibility on spatial and temporal integration in a coherent motion task, which was further compared to a steering control task under reduced visibility conditions for younger drivers. In the coherent motion task, displays consisted of a 2D array of dots, in which a portion of the dots moved in a uniform direction (i.e., being coherent) and the remaining dots moved in random directions (i.e., noise). Participants were instructed to report their perceived direction of the moving dots. Dot density, dot contrast, and dot lifetime were manipulated while coherency threshold was measured. In the steering control task, the visibility of the scene was manipulated by varying the quantity and quality of optical flow information. Nine participants were recruited to perform both the coherent motion task and the steering control task. We found that temporal integration and the quality of the stimuli affected performance on the coherent motion task. Global steering control performance was affected by optic flow quality, while local steering control performance was affected by the frequency of perturbation. Our analysis showed performance on the coherent motion task was correlated with local steering control performance under certain driving conditions. These results suggest that under reduced visibility conditions, temporal integration of visual information may play a larger role in steering control.

63.315 Navigation patterns and spatial perception with and without vision using assistive technology for the blind

Shachar Maidenbaum[1,3](shachar.maidenbaum@mail.huji.ac.il), Daniel-Robert Chebat[1,2], Shelly Levy-Tzedek[1,2], Amir Amedi[1,2,3,4]; [1]Hebrew University department of Medical Neurobiology, [2]Hebrew University, ELSC, [3]Hebrew University, IMRIC, [4]Hebrew University, BDRC

How does lack of vision affect the route one takes through an environment? How does this route change when different assistive tools are used? These questions have significant repercussions as Orientation and Mobility in unknown places pose one of the main challenges facing the blind. Currently, dedicated programs exist for helping the blind learn to navigate using the traditional white-cane. Throughout the years these programs were refined and were shown to significantly improve mobility. From this research have also emerged navigation patterns of white-cane users. Over the past decades many new devices have been developed for the blind. These devices offer different, and often more, information than the traditional white-cane, and may require different patterns of navigation and training for optimal use. Additionally it is unclear how useful some of these parameters, such as increased distance, actually are for non-visual navigation. Here, we use a series of virtual environments to explore the differences in navigation when using the virtual-EyeCane electronic travel aid (which offers increased distance information), when using a virtual version of the traditional white-cane, without using a device at all and when navigating visually. We show that the characteristics of navigating with the virtual-EyeCane differ from those of white-cane users and from navigation without an assistive device, and that virtual-EyeCane users complete more levels successfully, taking a shorter path and with less collisions than users of the white-cane or no device. Finally, we demonstrate that virtual navigation with the virtual-EyeCane takes on patterns relatively similar to those of navigating visually. In conclusion, these results suggest that navigation patterns learned from the white-cane are not necessarily optimal for other devices and that additional distance information is enough to change spatial perception and navigation patterns from those customarily used by the blind to patterns more similar to the sighted.

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63.316 Interactions of Hand And Gait Kinematics

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Introduction: We perform reaching-to-grasp and obstacle negotiation tasks dozens of times each day during activities of daily living using vision in a feed-forward manner to plan the necessary digit placements and grip aperture and/or foot placements and clearance heights to avoid the negative consequences of a collision with the target or obstacle. Previous research has shown that independently, spatial parameters of grasping and stepping are scaled according to the size of the target being grasped or crossed; however, the concurrent influence of these activities has yet to be investigated. Methods: Sixteen young adults completed walking trails in six conditions. The conditions were differentiated by the presence of an obstacle at the midpoint of the walkway (OBSTACLE, NO OBSTACLE) and the necessity to pick up a cylindrical container from a platform (TARGET, NO TARGET). The OBSTACLE and TARGET trials were further differentiated by the height of the obstacle (LOW, HIGH) and the size of the target container (SMALL, BIG) respectively. Standard spatiotemporal parameters of grasping and obstacle crossing were collected using motion capture cameras. Results: The obstacle was contacted in 1.4% of trials. When participants grasped the BIG target the lead limb crossing step length and lead and trail limb crossing step velocities were significantly decreased ($p<.05$). A significant OBSTACLE x TARGET interaction was observed for trail limb crossing step length with larger decreases observed when crossing the HIGH obstacle and concurrently grasping the BIG target ($p<.05$). Grasp kinematics were scaled to the size of the container. Conclusion: In this study participants prioritised the accurate grasping of the target as opposed to the obstacle crossing. This finding has important safety implications for the elderly and patient groups who experience greater difficulty dividing cognitive resources between concurrent motor tasks. This consideration is directing our future research with an active elderly population.

63.317 Speed judgments of background motion and illusion of self-motion when viewing sinusoidal visual stimuli along fore-and-aft axis with different frequencies and velocities

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Motivation: The ability to accurately judge the speeds of background motion is crucial for many daily tasks, such as driving. While viewers who experienced illusion of self-motion (vection) tend to overestimate the speed of a moving object (i.e., positive perceived speed bias (PSB): Gray and Regan, 2000), little is known about the effect of vection on speed perception of a moving visual background. Experiment: In this study, vection was provoked by viewing a wide field-of-view (horizontal: 220° x vertical: 56°) radial checker-board pattern oscillating in sinusoidal motions along the fore-and-aft axis. There were 5x5 full-factorial experimental conditions studying different combinations of RMS velocities (from 11 m/s to 178 m/s) and oscillation frequencies (from 0.05 Hz to 0.8 Hz). Subjects were required to estimate their perceived vection as well as their perceived speeds of the visual background motion using a ratio-scale method with a reference stimulus (0.2 Hz with 44 m/s). Ten subjects completed four repetitions for each condition. Results: In general, perceived vection was not significantly correlated with PSB (Spearman: rho=.017, p=.584). However, when frequencies were lower (below 0.2Hz) or velocities were higher (above 89 m/s), the presence of vection was associated with significantly higher positive PSB (Spearman: rho>.2, $p<.01$). We also observed that frequency of the stimuli had significant effects on PSB as well as on vection perception which were opposite to the effects of velocity. In short, impacts of frequency and velocity were in opposition. Conclusion: The presence of vection encouraged the viewers to increase their perceived speeds but such effect was modulated by both frequency and velocity of the background motion.

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63.318 **Do Geographical Slants Feel Steeper Than They Look?**
Alen Hajnal[1](alen.hajnal@usm.edu), Jeffrey Wagman[2], David Bunch[1], Jonathan Doyon[1]; [1]Department of Psychology, University of Southern Mississippi, [2]Department of Psychology, Illinois State University

Kinsella-Shaw, Shaw, and Turvey (1992) have shown that nonvisible surface slant perceived haptically by foot is matched with visually perceived slant by a factor of 0.81. Hajnal, Abdul-Malak, and Durgin (2011) have demonstrated that the same slope perceived visually without standing on it appears shallower than when stood on without looking. We asked participants to judge whether they would be able to stand on a ramp. In the first experiment, visual inspection was compared with trials in which participants took half a step with one foot onto an occluded ramp. Visual perception closely matched the actual maximal slope angle that one could stand on. However, the maximum slope angle based on perception by foot was significantly lower. We suspected that the additional balance task of standing on one foot might cause distortion in haptic perception. In the second experiment we repeated the same except that participants sat in a chair. This manipulation resulted in no differences between modalities, and a perfect match between perception and action capabilities. In the third experiment we offered a direct test of whether balance may cause a split between vision and haptics, by having participants hold onto a sturdy tripod while standing on one foot in the haptic condition. We obtained the same modality differences as in the first experiment. This led us to conclude that differences in the range of motion at the ankle and knee joints may play a role in pedal perception. The range of motion is larger while sitting down compared to when standing, thus potentially causing distortion of haptic perception. Implications for ecological theory (Gibson, 1979) will be offered by discussing the need for multisensory integration, instead of nonrepresentative comparisons of modalities tested in isolation.

63.319 **The Effects of Stress on Distance Perception**
Monica Rosen[1](rosen.monica@knights.ucf.edu), Joanna Lewis[1], Daniel McConnell[1], Mark Neider[1]; [1]Department of Psychology, University of Central Florida

Although there has been a great deal of research on binocular distance perception (Foley, 1980; Gogel, 1977), a number of questions remain unexplored. One such question involves how our ability to perceive distances is influenced by fitness and stress (internal and external), a combination of task demands and factors often encountered by first responders. Previous research has shown that kinesthetic stress (via backpack weight) influences a person's ability to accurately judge distances (Proffitt, Bhalla, Gossweiler, & Midgett, 2003). In the current study, we both attempted to replicate and extend on previous work by exploring the effects of cardiovascular fitness (CVF) and anxiety on distance perception. Anxiety was measured using the State-Trait Anxiety Inventory test (Spielberger, Reheiser, & Sydeman, 1995) and CVF was measured using MET scores (Jurca et al., 2005). Participants were asked to verbally estimate distances and then walk blindly to the target while carrying a backpack weighing approximately 20% of their weight, which served as a physical stressor. We found that participants overestimated in the verbal task, but underestimated in the blind walking task, regardless of whether they wore a backpack or not. Interestingly, errors were approximately twice as large in the verbal task compared to the blind walking task as distance increased. Verbal judgment error was strongly, positively correlated between blocks, but blind walking was not, suggesting that the action oriented task (blind walking) may have been more sensitive to stress. Furthermore, there was a positive correlation between CVF and blind walking error for the second block of the heavy backpack condition, but not for the verbal error. Combined, our data support the assertion that verbal and action oriented tasks may be subserved by different neurophysiological networks (Bingham & Pagano, 1998).

Object recognition: General

Wednesday, May 21, 8:30 am - 12:30 pm
Poster Session, Jacaranda Hall

63.321 **Ideal Observer Analysis of Fused Multispectral Imagery**
Jennifer L. Bittner[1,2](jbittner@ball.com), M. Trent Schill[1], Leslie M. Blaha[1], Joseph W. Houpt[2,3]; [1]Air Force Research Laboratory, [2]Ball Aerospace, [3]Wright State University

Components (i.e. features) of an image are highlighted differently given enhancement with varying spectral bands. For example, a thermal (long-wave infrared) image of a scene may show a 'glowing' human but provide little other detail, whereas a visible image may show the scene detail but the human is much less apparent. Image fusion aims to find the optimal balance of emphasis by producing an image combination that is more informative and is more suitable for perception to ultimately enhance human visual performance (e.g. Toet, et al. 2010). The current project uses ideal observer analysis (Geisler 1989) to directly test the aims of image fusion. For a 1-of-8 identification task, we derived ideal performance and human processing efficiencies for viewing a set of rotated Landolt C images taken using individual sensor cameras and combined across a series of 7 fusion algorithms (e.g. Laplacian, PCA, discrete wavelet transformation, averaging). Contrary to the assumption that image fusion always produces a more informative combination image, both ideal observer and human efficiency results showed that the individual sensor imagery chosen can be just as influential as the fusion-enhanced images. Ideal observer results showed that the amount of information available (i.e. ideal performance) was influenced not by the fusion algorithm chosen but more often by the individual sensor combinations. Additionally, human efficiencies were found in similar ranges (~10-15%) for both individual spectral and fused imagery with humans performing better at times with the images from the individual sensors over those that were fused. As image fusion can be applied to a variety of image content, our current application of ideal observer analysis provides not only a thorough assessment of human performance with image fusion for simple letter-like features but sets up a framework for future evaluation for more complex stimuli and tasks.
Acknowledgement: AFOSR grant 12RH14COR

63.322 **Measuring image distortions using an Iterative Amsler Grid (IAG) in patients with age-related macular degeneration**
Inci Ayhan[1](inci.ayhan@boun.edu.tr), Edward Doyle[2], Johannes Zanker[3]; [1]Boğaziçi University, Department of Psychology, [2]Torbay Hospital, Department of Opthalmology, [3]Royal Holloway, University of London, Department of Psychology

Metamorphopsia, a condition experienced in age-related macular degeneration (AMD), manifests itself as the perceived distortion of the shape and tilt of objects. In the presence of metamorphopsia, straight lines appear to be curved and wavy to patient with AMD and some other retinal pathologies such as epiretinal membrane. The most common clinical tool to measure metamorphosia is asking patients to identify irregularities in the Amsler Grid, which is composed of equally spaced straight vertical and horizontal lines. Any distortions or missing regions in the grid are taken as a sign of a problem with the macula. Recently, we developed an iterative procedure (IAG), to obtain a reproducible and quantifiable map of visual deformations. In this procedure, curved horizontal and vertical line segments (perceived or physical distortions) are displayed on a computer monitor to probe different regions of the visual field and then adjusted by observers such that they appear straight. Control participants are able to reliably correct deformations that simulate metamorphopsia while maintaining fixation in the middle of the screen. In the current work, we obtained deformation maps from patients at various stages of AMD. For those patients, who were not confident using the computer mouse due to motor control problem or lack of practice with the computers, we collected data by following their oral instructions to the experimenter who then adjusted the tilt of line segments. Patients who had extensive scotomas or serious fixation problems were challenged by this procedure, but others were comfortable using the IAG method with generated deformation maps that did correspond to their subjective reports.
Acknowledgement: Gateway Seed Fund

63.323 **Intuitive statistics from graphical representations of data**
Sarah S. Pak[1](spak@princeton.edu), J. Benjamin Hutchinson[1], Nicholas B. Turk-Browne[1]; [1]Department of Psychology, Princeton University

The graphical display of quantitative information is indispensible for conveying scientific data in a concise and compelling manner. However, little is known about whether our impressions of visualized data align with the actual statistical properties of the data. In other words, is the visual system a good statistician? In the current study, we presented observers with data from two distributions side-by-side, rendered with each data point visible in vertical bee-swarm plots. Observers completed only one trial in which they were asked to judge which of the two distributions (or "groups") seemed higher overall. To test sensitivity for statistical variables, we manipulated the distributions such that their comparison resulted in p-values of 0.5, 0.05, or 0.005 according to a t-test. We further manipulated whether, relative to a reference difference of $p = 0.05$, higher/lower p-values arose from smaller/bigger differences in the means of the distributions or more/less variance within each distribution. Finally, we evaluated the importance of domain-specific knowledge about statistics by manipulating whether the data were framed as scientific (i.e., from a biology experiment) or non-scientific (i.e., from a high-jump competition), and by assessing whether observers had received formal training in statistics. Initial results

indicated that accuracy in choosing the higher distribution was above chance in all conditions (69% on average). However, accuracy was unaffected by the significance of the p-value of the difference between distributions, and this was true regardless of whether the means or variances were manipulated. Strikingly, observers who reported receiving statistical training had significantly lower accuracy than those who did not. Finally, there were hints that a non-scientific framing may boost accuracy under certain circumstances. These results demonstrate a general ability to compare distributions, but reveal a visual insensitivity to statistical variables over a dynamic range important to researchers for making scientific inferences.

63.324 **Parallel processing of multiple object identities from an ambiguous image: evidence from negative priming in a lexical decision task.** Elan Barenholtz[1,2](elan.barenholtz@fau.edu), Mohammed Islam[1]; [1]Dept. of Psychology, College of Science, Florida Atlantic University, [2]Center for Complex Systems, College of Science, Florida Atlantic University

A degraded image of an object (e.g., a blurry picture of a mushroom), may be consistent with two or more possible interpretations (e.g., mushroom, an umbrella, etc.), even if one interpretation is ultimately chosen for recognition. Do these various interpretations all get activated in parallel or is the preferred interpretation the only one to survive the recognition process? To address this, we presented participants with low pass images of objects in isolation that carried a "primary" interpretation (one that observers most frequently produced in a free-naming task) as well as a "secondary" interpretation (one that observers often produced when asked to consider alternative interpretations). These images were briefly presented (70 ms) and were then followed by a lexical decision task in which the participants had to determine whether a string of letters were a word or not. On word trials, the string consisted of a word that was semantically related to the primary interpretation, a word semantically related to the secondary interpretation, or a word that was semantically unrelated to either interpretation (control word). The main finding was that the recognition of words related to the secondary interpretation took longer than both the primary and control words (i.e., negative priming of the secondary words). This finding suggests that during the recognition process, alternate interpretations of an image are initially activated but then actively suppressed.

63.325 **Armored Vehicle Recognition Training Using Game-Like Feedback** Dustin Smith[1](dcsmith@wichita.edu), Lindsey Davies[1], Evan Palmer[1], Joseph Keebler[1]; [1]Human Factors Psychology, Wichita State University

Object recognition can be a challenging task when identifying objects with strong similarities in appearance. Military vehicles share structural similarities that can make recognition extremely difficult (O'Kane, Biederman, Cooper, & Nystrom, 1997). That difficulty contributes to misidentification errors and leads to 'friendly fire' accidents (Regan, 1995). To investigate armored vehicle identification training methodologies, this study examined the effect of adding gamelike features to a two alternative forced choice (2AFC) combat vehicle identification training tool. Twenty-six undergraduate students were recruited and received course credit for their participation. They were trained using a 2AFC task that presented gamelike feedback for each training trial. Trials consisted of, a display that presented the name of a vehicle (e.g. M1A1) followed by two images. Participants had to choose which image was associated with the initial name presented. After which, appropriate feedback was presented based on the accuracy of their guess. That is, guessing correctly was coupled with positively valenced arousing sound effects and points as feedback for each training trial. Participants learned seven armored vehicles across six training blocks that lasted approximately two minutes each. Overall performance in the training phase was 74.9% (SD = 11.06%) correct and was significantly greater than chance (i.e. 50%). Participants' training performance significantly improved as the experiment progressed. That is, participants achieved 80.7% accuracy after four training blocks (approximately eight minutes of training). In addition, participants' correct trial response times significantly decreased. Therefore, it seems that participants became more accurate and faster as they interacted with the game-like 2AFC training. Future research will compare the learning effects of the gamelike 2AFC tank training to a control group without gaming features, explore the effects of gamification on different training modalities (i.e. augmented reality), and examine the effects of learning more vehicles.

63.326 **Action Video Game Exposure Modulates Spatial Frequency Tuning for Emotional Objects** Laurent Caplette[1](laurent.caplette@umontreal.ca), Greg L. West[1], Bruno Wicker[2], Marie Gomot[3], Frédéric Gosselin[1]; [1]Département de psychologie, Université de Montréal, [2]Institut de Neurosciences de la Timone, CNRS UMR 7289 & Aix-Marseille Université, [3]INSERM U930, CNRS ERL 3106, Université François-Rabelais de Tours

Frequent action video game playing is known to influence perceptual, cognitive and emotional processes (Bailey & West, 2013; Dye et al., 2009; Li et al., 2009). Here, we examined the impact of habitual action video game exposure on the use of spatial frequencies (SF) during an object recognition task. Base images consisted of objects with low (e.g., a phone) or high (e.g., a gun) emotional value. All stimuli were equalized in spatial frequency content. Multiple spatial frequencies were sampled randomly for each stimulus on each trial. Images were presented for 300 ms, followed by a name corresponding or not to the object. A group of 18 non gamer subjects and a group of 17 gamer (>10 hours/week) subjects had to decide if the name matched the object as quickly as possible without making too many errors. To study the impact of different SFs on reaction time (RT), we performed linear multiple regressions on the random filters and RTs for correct responses in trials where object and name matched. For all subjects, SFs between 14.90 and 26.14 cycles per image (cpi) led to faster responses ($p<0.05$). Moreover, SFs between 14.60 and 24.44 cpi led to faster RTs for emotional objects ($p<0.05$), suggesting that the intrinsic affective value of an object influences its processing. We then computed an index comparing the use of high and low SFs for each group in every condition and compared it between groups to study possible differences. This revealed that low SFs of emotional objects led to faster recognition than high SFs in action video game players, while the opposite pattern was observed in non video game players (SF use indexes = -0.61 and 0.57 respectively; $t31.62 = 2.29$, $p = 0.029$). Habitual action video game exposure thus impacts internal representations of emotional objects.

63.327 **Discriminating between different targets during a single trial using RSVP and EEG** Melissa A. Smith[1](mabsmith@gmail.com), Eric J. Blumberg[1], Matthew S. Peterson[1]; [1]Human Factors & Applied Cognition Program, Department of Psychology, George Mason University

Rapid serial visual presentation (RSVP) has been used extensively in cognitive studies, with findings related to its effect on attentional blink being extensively studied (Shapiro, et al, 1994; Maki, et al, 1997). EEG studies utilizing RSVP methods typically focus on whether a target is present or absent, keeping the discrimination to two levels (Luo & Sajda, 2009; Huang, et al, 2011). The pilot study presented here examined if 3 levels, a target, a lure, and a control nature scene, could be distinguished by EEG classification using RSVP; all three levels contained similar nature scenes, though the target and lure scenes contained vehicles. 3 participants were included in the study. Participants trained on 6 different tanks from the Recognition of Combatants-Vehicles (ROC-V) program for a set period before the experiment. During the experiment, 6 blocks (one per tank) were presented; within each block, 72 20-image RSVP streams were shown: 1/3 of the trials were targets, 1/3 were lures, and 1/3 were control nature scenes. Within each RSVP stream, a target or lure could only appear once, with the remaining images comprised of nature scenes. Participants were instructed to respond if they saw the tank (target trial), a non-target vehicle (lure trial), and to withhold response if no vehicles were seen (control trial). Linear discriminate analysis (LDA) showed best classifcation; five-fold cross validation showed an average 92.5% hit rate, 18% false alarm rate in the discrimination of the EEG data for targets vs. control, and a 77.5% hit rate, 27.5% false alarm rate for targets vs. lures. These results indicate that it is possible to classify specific objects, not just absence or presence, when using RSVP with EEG classification. This material is based upon work supported by the Army Research Office under Award No. W911NF-12-1-0213.

Acknowledgement: This material is based upon work supported by the Army Research Office under Award No. W911NF-12-1-0213.

63.328 **The Duration of Pleasure In the Experience of Beauty** Lauren Vale[1](lauren.vale@nyu.edu), Denis G. Pelli[1]; [1]Psychology Deptartment and Center for Neural Science, New York University

George Santayana (1896) defines beauty as the pleasure we attribute to an object. Immanuel Kant (1764) claims that beauty requires thought. We hypothesize that what distinguishes beautiful from merely pleasant things is beauty's lingering pleasure, after the object is gone. So we measure the time course of pleasure. People differ in what they find beautiful, so we begin by asking the observer to select an object (painting or photograph) that is beautiful and another that is pretty but not beautiful. We also provide a pleasant object, asking the observer to stroke an alpaca-fur teddy bear. Every 20 seconds, we ask observers to rate the pleasure (0-10) that

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they get from the object. We present the stimulus for 2 minutes, and record the observer's responses for 4 minutes. We study the decay of pleasure over time after stimulus withdrawal. In every condition, after stimulus offset, the pleasure decays nearly exponentially, and we estimate the 1/e time constant of the decay (τ). The pleasure lingers much longer after something beautiful (τ=544±105 s) than after something pretty or pleasant (τ=56±47 or 67±25 s, n=3). Further, we find that certain word-task conditions (reciting the months, remembering a phone number, or repeatedly hearing one's name) do not affect the pleasure of pretty and pleasant objects, yet curtail the duration of a beautiful object's pleasure to that of pretty and pleasant. (In those cases, observers say they didn't experience beauty.) Thus, indeed, lingering pleasure may be the hallmark of the beauty experience. Beauty's residual pleasure lasts ten times longer than that of pretty and pleasant, and is extinguished by our word-task conditions. Why are the word tasks so effective and selective in extinguishing the pleasure of beauty while sparing pretty and pleasant? Perhaps, as Kant said, beauty requires thought.

63.329 **Mirror-image confusion in object-selective cortex: Are all reflections alike?** Miles Hatfield[1](hatfield@cogsci.jhu.edu), Michael McCloskey[1], Soojin Park[1]; [1]Department of Cognitive Science, Johns Hopkins University

A substantial body of research has demonstrated that mirror-reversed views of objects are especially difficult to distinguish (Corballis & Beale, 1976; Davidoff & Warrington, 2001; Rollenhagen & Olson, 2000). However, not all mirror images are equal: participants show a greater tendency to confuse reflections about the object's principal axis (OPA) than left-right reflections of the object about an external vertical axis (EVA) (Gregory & McCloskey, 2010; Gregory et al., 2011). Using an event-related fMRI adaptation paradigm, we examined mirror-image specificity and invariance in human object-selective cortex [lateral occipital (LO) and posterior fusiform (pFs)] and orientation-selective occipito-parietal junction (OPJ) (Valyear et al., 2006). Participants (N=17) viewed an object stimulus, followed by the same view repeated (Identical condition), an object-axis reflection (OPA), an external-axis reflection (EVA), or a different object (Diff). In LO, neither mirror image condition produced any adaptation (no difference from Different condition). In contrast, for pFs, both mirror image conditions were adapted relative to the Different condition (Diff vs. OPA: $F(1,39) = 25.24$, $p < .05$.; Diff vs. EVA: $F(1,39) = 12.97$, $p < .05$). Additionally, pFs adapted fully (no difference from Identical condition) to OPA reflections but not to EVA reflections (Identical vs. EVA: $F(1,39) = 14.58$, $p < .05$), and orientation-selective OPJ showed a similar trend towards releasing from adaptation only for EVA reflections, though OPA and EVA did not differ directly (both F's <3, n.s.). These results shed light on the neural representation of object orientation, and suggest the possibility of greater invariance to object-axis reflections than external-axis reflections in both ventral (pFs) and dorsal (OPJ) streams, consistent with the greater behavioral confusability for object-axis reflections (Gregory & McCloskey, 2010).

63.330 **Dynamic Perception: Synergy between Grouping, Retinotopic Masking, and Non-retinotopic Feature Attribution** Haluk Ogmen[1,2](ogmen@uh.edu), Michael Herzog[3], Babak Noory[1,2]; [1]Dept. of ECE, University of Houston, [2]Center for Neuro-Engineering & Cognitive Science, University of Houston, [3]Laboratory of Psychophysics, Brain Mind Institute, EPFL

Purpose: Due to visible persistence, moving objects should appear highly blurred with their features blending to those of other objects or the background. This does not occur under normal viewing conditions. We proposed that clarity of vision is achieved through a synergy between grouping, retinotopic masking, and non-retinotopic feature attribution. Here, we investigated the retinotopy of visual masking, non-retinotopic feature attribution, and their relationship to perceptual grouping. Methods: We used a radial Ternus-Pikler Display (TPD) in which the target and mask were positioned either according to retinotopic coordinates (retinotopic mask) or according to non-retinotopic grouping (non-retinotopic mask). Two ISIs were used to generate element and group motion percepts in the TPD. In experiment 1, we used a metacontrast mask that produced non-monotonic (type-B) masking. In experiment 2, we used a structure mask that produced monotonic (type-A) masking. To study feature attribution, in Experiment 3 we made the direction of the TPD predictable. In all experiments, observers kept steady fixation at the center of the display and eye movements were monitored in control experiments. Results: Retinotopic masking predicts masking effects only for retinotopic masks for both element and group motion percepts in TPD. In contrast, non-retinotopic masking predicts masking effects for retinotopic masks only for element motion percepts in TPD and masking effects for non-retinotopic masks only for group motion percepts in TPD. Our results are consistent with retinotopic masking effects for both metacontrast and structure masks and for type-A and type-B masking functions. In Experiment 3, the retinotopic mask maintained its masking effect in element motion percept but not in the group motion percept, indicating effective non-retinotopic feature attribution in the latter case. Conclusions: Our results suggest that retinotopic masking controls motion blur while non-retinotopic feature attribution allows the computation of form across space and time.

Visual memory: Capacity and resolution

Wednesday, May 21, 8:30 am - 12:30 pm
Poster Session, Jacaranda Hall

63.331 **A measure of working memory capacity using a 3D videogame.** Guillaume Doucet[1](guillaume.doucet2@mail.mcgill.ca), Julio Martinez-Trujillo[1]; [1]Cognitive Neurophysiology Laboratory, Department of Physiology, McGill University

Working memory (WM) capacity measurements are typically taken in laboratory settings using 2D stimuli and delay periods devoid of sensory stimulation. However, this situation is almost inexistent in real life where our senses are constantly bombarded with 3D sensory signals. We have therefore designed a 3D videogame (Game of Runes) to measure and train WM capacity, using a commercial videogame engine (Unreal). The engine allows simulation of realistic environments with precise control over events timing and stimulus complexity. On each trial, 2 to 8 sample items were simultaneously presented at random positions on a virtual surface (15 possible locations) for a total duration of 0.5 seconds × # of items. Stimuli consisted of Futhark Runes, a pre-Germanic alphabet containing 24 characters, sufficiently different from the Latin alphabet to prevent word formation. Following stimuli presentation, the player was required to navigate in a rich environment to the test section (variable delay period; median: 5.397 seconds). For successful trial completion, the player had to select each remembered rune amongst 16 randomly chosen test runes. To evaluate WM capacity (N), we fitted probability distribution functions (PDF; N=2-8 items), to each player's performance (percent of correct trials per # of items). Using a least squares algorithm, we determined the average capacity across 8 subjects to be 5 items. Finally, upon investigating the time difference between each rune's selection, we found no major discrepancies amongst rune number 3, 4, and 5 (Ranksum Test; $p=0.03$, $p>0.05$, $p>0.05$ respectively), however, there was a clear increase in selection time for rune 6 ($p=0.0001$), suggesting that subjects start guessing after remembering 5 items. We further observed, in at least one subject, an increase in N after playing multiple games. Our results show that 3D videogames can serve to measure and train WM capacity, yielding at least similar results as conventional methods.

63.332 **Estimating Transsaccadic Memory Capacity for Visual Search** Nicholas Kleene[1](nkleene88@gmail.com), Melchi Michel[2]; [1]Psychology Department, Rutgers University

Transsaccadic integration is the process whereby we combine information across visual fixations and, as such, plays an important role in many visual tasks including visual search. Because information from previous fixations must be preserved to allow integration with the current fixation, a necessary component of transsaccadic integration is transsaccadic memory (TSM). We developed an ideal observer model of transsaccadic integration that takes into account the critical role of TSM and used this model to estimate a lower bound on TSM capacity in a simple visual search task. Prior to the main experiment, subjects completed a forced-choice detection experiment, allowing us to measure their psychometric functions at each potential target location. Subjects then performed a visual search task that required localizing a target signal in noise. In this initial study, we used a single-fixation paradigm to control for variations in visual sensitivity across the visual field. We simulated successive visual fixations using multiple intervals, and saccades using visual 'sweeps'. In each block subjects were presented with one, two, or four intervals of 1/f noise. A Gabor target was present in every fixation interval (redundancy condition), or only one (uncertainty condition). Performance was measured as the proportion of trials in which subjects correctly localized the target. The ideal observer model allowed us to place a lower bound on each subject's TSM capacity, quantified in terms of the minimum amount of memory (in bits) required to explain the search performance obtained for that subject. Across subjects, this estimated lower bound on TSM capacity was about 5.5 bits, with bounds for all subjects increasing as a function of the number of fixation intervals. We discuss the relationship of our obtained bounds to previous estimates of transsaccadic memory and visual short term memory and to existing accounts of the role of visual memory in search.

63.333 **Dynamic reallocation of resources in visual short-term memory**
Summer Sheremata[1](ssheremata@gwu.edu), Sarah Shomstein[1]; [1]Department of Psychology, George Washington University

Visual short-term memory (VSTM) is a capacity-limited system for maintaining visual information across brief durations of time. Hemispheric asymmetries are apparent in VSTM within topographically defined regions of the parietal lobe (Sheremata et al., 2010). Consistent with topographic mapping, the left hemisphere coded items in the right, or contralateral, visual field. Importantly, as memory load increased, the right hemisphere coded items bilaterally. These neuroimaging results suggest that memory demands modulate right parietal cortex representations, setting forth the prediction that memory performance across the visual field varies based upon memory demands. Because activity in posterior parietal cortex reflects feature-load dependence during VSTM (Xu & Chun, 2006), we predicted that differences in performance should occur in a feature-load dependent manner. In a series of experiments, we investigated the effects of feature-load on dynamic reallocation of resources in VSTM. In each experiment, participants performed a change detection task in which either color or shape could change. In the single-feature condition, participants were cued to a single feature, while in the two-feature condition either feature could change. Our results demonstrate feature-load dependent changes in visual field bias. First, we demonstrated a reduced feature cost for items in the right visual field. We then excluded the possibility that hemispheric asymmetries could be caused by perceptual or decision-making processes, and demonstrated that hemifield asymmetries occurred within randomized blocks. Finally, we hypothesized that if VSTM task demands result in a reallocation of resources from the left to right visual field, then task-set should guide this reallocation. We found that VSTM performance is modulated by manipulating task-set, demonstrating direct evidence for the role of VSTM task demands on hemifield asymmetries. Consistent with hemispheric asymmetries reported in functional imaging, these experiments demonstrate that VSTM task demands result in a dynamic reallocation of resources across the visual field.

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63.334 **Visual working memory represents information less precisely than iconic memory without necessarily trading off the precision for a larger capacity**
Daegyu Kim[1](se2p00@nate.com), Jooseok Hyun[2]; [1]Department of Psychology, Chung-Ang University, [2]Department of Psychology, Chung-Ang University

While visual working memory (VWM) has limited storage capacity, maintaining stored information for a few seconds, its predecessor, iconic memory (IM), has no such limit but holds stored information for only a few hundred milliseconds. Despite this difference, the exact nature of this trade-off has been relatively unclear. To examine this trade-off, we compared the precision of IM and VWM representations in memory (i.e., s.d.) and the probability of holding test-relevant items in memory (i.e., Pm), by utilizing the mixture model proposed by Zhang and Luck (2008). In the experiment, each trial displayed 3 or 6 colored squares as a sample for 500 ms, followed by a 30- or 900-ms blank display (i.e., IM versus VWM). After the blank display, a retro-cue for a recall item in the sample appeared at one of the sample item locations for 970 or 100ms. Therefore, leaving the same length of a 1s-delay interval on both IM and VWM conditions, the retro-cue yet differing depending on if it appeared within the interval of iconic persistence (<350ms) or beyond it. The recall performance corresponding to the model demonstrated a higher Pm for the IM condition than for the VWM condition, which was more evident in the set size 6 condition than in the set size 3 one. The s.d. was also lower for the IM condition overall, but this advantage was constant across the set size conditions. These results indicate that IM outperforms VWM, by holding more items with better precision overall, but their efficiencies for the representational precision do not much differ. These findings further suggest that the VWM capacity limit may arise primarily from the overall degradation of the iconic representations, forcing a selective storage of the representations, but their precision is set constant, without being traded off for a larger capacity.

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63.335 **Attentional Priority Determines Working Memory Precision**
Zuzanna Klyszejko[1](zk327@nyu.edu), Masih Rahmati[1], Clayton E Curtis[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Visual working memory is a system used to hold information actively in mind temporarily. The number of items and the precision with which we can store information has limits that define its capacity. How much control do we have over the precision with which we store information when faced with these severe capacity limitations? Here, we tested the hypothesis that attentional priority determines the precision of working memory representations. We conducted two psychophysical experiments that manipulated the item priority. In Experiment 1, we varied the probabilities with which memorized items were likely to be tested. In Experiment 2, we varied priority by varying monetary incentives contingent upon successful memory for items tested. Moreover, we formalize our hypothesis using a simple generative computational model that distributed attentional resources across items with different priorities. We found strong evidence in both experiments that priority affects the precision of working memory in a manner that matches the response output of our model. Our results demonstrate that representations of priority may provide a mechanism by which resources can be reallocated to increase the precision with which we encode and store information in a capacity limited system

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63.336 **Training on orientation recall improves the precision of visual short-term memory under high and low levels of memory masking**
Alexander A. Petrov[1](apetrov@alexpetrov.com), Nicholas M. Van Horn[1]; [1]Department of Psychology, Ohio State University

The effect of practice on visual short-term memory (VSTM) is unclear. While some studies found no improvement in VSTM capacity through training, it is not clear what effect practice has on the fidelity of information in VSTM. The observers in the present study trained on a continuous orientation recall task under strong or minimal memory masking interference. Method: Seventeen observers completed an orientation recall task across six one-hour sessions. After a 4.25 second retention interval, the observers entered a continuous response by directly manipulating a match Gabor to the remembered orientation of a sample. During the retention interval, the observers completed a concurrent orientation discrimination-task on a target Gabor. The discrimination boundary was identical to the mean sample axis across trials in the "congruent" group, and was orthogonal to it in the "incongruent" group. The discrimination Gabor served as a memory mask, but was otherwise unrelated to the recall task. The sample orientation, and therefore congruency, was switched during pre- and post-tests. Results: The initial recall precision (1/sd(error)) was statistically indistinguishable in the two groups. The precision improved significantly across training sessions in both groups, but the incongruent group improved faster and by a larger amount (42% improvement in the incongruent vs. 21% in the congruent group). Post-tests on switched congruency conditions revealed nearly complete transfer of learning for both groups. Discussion: These results demonstrate that training can increase VSTM precision and that congruent masks impeded learning more than incongruent masks. Critically, training on incongruent stimuli led to congruent-precision greater than the asymptotic precision obtained with congruent training. This suggests that observer's strategies may play an important role in the improvement of VSTM precision, particularly in the face of perceptual interference.

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63.337 **Testing enhances the probability but not the precision of memory recall**
David Sutterer[1](sutterer@uoregon.edu), Edward Awh[1]; [1]Department of Psychology, University of Oregon

Numerous studies have demonstrated that retrieval from long term memory (LTM) can enhance subsequent access to that memory, a phenomenon labeled the testing effect (Carrier & Pashler, 1992). However, the testing effect has been primarily been studied with verbal/categorical stimuli. Consequently, it has not yet been determined whether the testing effect impacts the probability of successful memory retrieval or the quality of the retrieved representation. To answer this question, we examined LTM for the color of 400 unique images. After every 10 images subjects (n=20) either recalled each of the ten colors or were given a chance to restudy the items. After a 30 minute delay, subjects selected the color of each of the previously learned images from 360 degrees of continuous color space. Using a mixture model analysis (Zhang and Luck, 2008) we determined the probability and quality of the recalled color. A robust testing effect was observed; subjects recalled a significantly higher proportion of items that they had previously retrieved relative to items that they had restudied ($p < .01$). Inter-

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estingly, this boost in storage probability was accompanied by a decrease in mnemonic precision such that mnemonic precision was significantly worse for items subjects were asked to retrieve from memory relative to restudy (p <.05). This decline in precision appears to be at least partially explained by a tendency for delayed recall responses to be biased towards the (imperfect) responses that were made in the immediate recall portion of the retrieval condition (r=.26), a tendency that was absent in the restudy condition (r=.03). Thus, the testing effect enhances the probability of successful recall but it comes with a cost; the learned associations are shaped by the imperfect representations that are formed during retrieval practice.

63.338 **Both variations in perceptual sensitivity and decisional response bias contribute to visual working memory performance**

Young Eun Park[1,2](youngeun.park@vanderbilt.edu), Rosanne Rademaker[3], Frank Tong[1,2]; [1]Department of Psychology, Vanderbilt University, [2]Vanderbilt Vision Research Center, Vanderbilt University, [3]Cognitive Neuroscience Department, Maastricht University, Maastricht, The Netherlands

Current models of visual working memory have conceptualized this system as consisting of either discrete slots with fixed visual precision or a flexible resource that leads to variability in memory precision across items. However, these models have paid little attention to the possibility that precision may also depend on the perceptual sensitivity of the visual system at encoding specific items. Also, they have not considered the extent to which decisional response bias might influence working memory performance. To investigate these contributions, we conducted an experiment in which participants were presented with a circular array of 1-6 oriented gratings, and subsequently had to report the orientation of a probed item by rotating a central test grating. Using a mixture-model analysis, we observed a pronounced "oblique effect", with better memory precision found for cardinal than oblique orientations at every set size tested. This effect was prominent even at set size 1, when full attentional resources could be directed to a single item, implying that memory precision was limited by orientation sensitivity. Additional analyses revealed a decisional response bias in favor of reporting an orientation that happened to be formed by the angle between the point of fixation and the location of the probed item, as well as the angle orthogonal to this arbitrary orientation. This bias was evident only at large set sizes that exceeded typical estimates of memory capacity, which is suggestive of a guessing strategy that participants use when their knowledge of the true orientation is deemed unreliable. Overall, our findings demonstrate that the perceptual sensitivity of the visual system introduces a systematic variability in memory precision. Moreover, large display sizes lead to a more prevalent response bias, a finding that is not readily predicted by resource models that assume that all items in a display can be successfully retained.

63.339 **Moved here and forgot there: Saccades deteriorate visual short-term memory for non-target locations**

Martin Rolfs[1,2](martin.rolfs@hu-berlin.de), Sven Ohl[1,2]; [1]Bernstein Center for Computational Neuroscience Berlin, Germany, [2]Department of Psychology, Humboldt University Berlin, Germany

Visual short-term memory allows humans to recall what they have just seen when the sensory input has disappeared from view, and many psychophysical studies have revealed its fragile nature. Here, we show that saccadic eye movements, planned and executed after the disappearance of a visual stimulus array, strongly bias memory performance in favor of the targets of saccades. Observers fixated the center of an array of test locations, highlighted by landmarks evenly arranged on an imaginary circle. After 500 ms of fixation, a memory array—consisting of Gabor patches with varying degrees of tilt—appeared inside the landmarks for 100 ms and then disappeared again. Another 400 ms later, a central movement cue instructed observers to make a saccade to the indicated location. Following saccade execution, and a total of 1200 ms after the disappearance of the memory array, a response cue highlighted a landmark previously occupied by a memory item, prompting participants to report its remembered orientation (clockwise vs. counterclockwise relative to vertical). Despite the fact that saccades went as often to the test location as to any other location in the array, memory performance was markedly better when the saccade had targeted the test location. Modeling memory performance as a function of the magnitude of tilt of the test item revealed that items at non-target locations were forgotten more often (irrespective of the magnitude of tilt), but that remembered items were retained in memory with a similar degree of fidelity (as measured by the just noticeable difference), irrespective of whether the saccade had targeted its location. These results reveal a strong impact of saccadic eye movements on visual short-term memory and highlight the crucial role of action for which parts of a scene we remember and which we forget.

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63.340 **Recall and Recognition Effects on Retro-Cue Benefit**

Filiz Gozenman[1](filizg@gmail.com), Ryan T. Tanoue[1], Terina Metoyer[1], Marian E. Berryhill[1]; [1]University of Nevada, Reno

What happens to the representations of items in visual working memory (VWM) when attention shifts to a single item? Here, we investigated the fate of these uncued items using a retroactive cuing paradigm. This paradigm presents attentional cues after the VWM maintenance duration but prior to memory test. The retro-cue was either neutral cue (no information), valid (the cued item was probed), or invalid (an uncued item was probed). Additionally, retrieval demands and key temporal parameters were manipulated. First, VWM was tested using recognition and recall probes to determine coarse accuracy and fidelity measures of the uncued representations. Second, the delay between the retro-cue and the memory probe varied to monitor the time course of these representations. In a series of experiments we found that when measured coarsely using recognition probes, VWM performance reveals no significantly detriment of the uncued item when compared to neutral trials even up to durations of 24 s. However, there is a consequence to being an uncued item demonstrated by the finer grained measure of recall. The accuracy of recall performance declines with longer delay durations indicating that the fidelity of the uncued representations is subject to significantly greater degradation than neutral or valid cue conditions. In summary, the retro-cue attracts internal attention to the representation of the cued item and preserves it without eliminating uncued items from VWM, but they are not protected and decay more rapidly.

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63.341 **The effects of spatial proximity and colour similarity on competition between targets and distractors on visual working memory.**

Fiona McNab[1](F.McNab@bham.ac.uk), Jumana Ahmad[1], Dipesh Mistry[1], Anna Nobre[2], Kimron Shapiro[1]; [1]School of Psychology, University of Birmingham, Birmingham, UK., [2]Oxford Centre for Human Brain Activity, University Department of Psychiatry, University of Oxford, Oxford, UK

The ability to filter distractors in visual working memory (VWM) is important for VWM performance. However, the factors that affect such filtering, and possible interactions between them, are still a matter of debate. It is known that stimuli compete for attention, in turn affecting VWM performance, with both feature similarity and type of presentation (simultaneous versus sequential) shown to be important factors. Here we investigate the effects of target-distractor feature similarity, spatial proximity, and their interactions on VWM. Young adults (18-30 years) were asked to remember the colours of a column of three shapes (targets). Two other columns of shapes were shown, either on the left of the right of the targets. One was close to the targets and the other far from the targets. In the "spatial near" condition the shapes in the near column were coloured (distractors), and the shapes in the far column were unfilled outlines. In the "spatial far" condition the shapes in the far column were coloured distractors. Distractors were similar or dissimilar in colour compared to the targets. Participants responded by indicating the colour of a specified target by clicking on a colour wheel. We used a within-subjects design and measured VWM precision. Results suggest that the factors of target-distractor spatial proximity and colour similarity interact, such that greater colour similarity is associated reduced WM precision when targets and distractors are close in space. Our results support a growing body of evidence indicating that competition between stimuli affects VWM performance and underscore the importance of considering multiple factors in the experimental design of such studies.

Acknowledgement: Wellcome Trust

63.342 **Mechanisms of distractor interference in visual working memory**

Kimron Shapiro[1](k.l.shapiro@bham.ac.uk), Risa Sawaki[1]; [1]University of Birmingham, UK

Interference by external visual inputs has been shown to impact the ability to maintain information in visual working memory (VWM). However, the mechanism underlying this interference is not well understood. It is possible that distractor interference on visual working memory is not automatic but is instead a form of active attentional control based on the nature of the interfering stimulus. Using a modified change-detection paradigm where participants were required to encode the color of a single square, the present study investigated this issue by manipulating the relationship in colour space between to-be-remembered (target) and to-be-ignored (distractor) stimuli. The results provide evidence of active attentional control on VWM interference depending on the proximity in color space between the target and distractor.

63.343 Deriving configuration effects in spatial working memory from rational correspondence Jorge Aurelio Menendez[1](j.audi11@gmail.com), Gi Yeul Bae[1], Colin Wilson[2], Jonathan Flombaum[1]; [1]Johns Hopkins University Department of Psychological and Brain Sciences, [2]Johns Hopkins University Department of Cognitive Science

Groups, gestalts, and configurations—these vaunted constructs in perceptual psychology typically connote representational contents to be distinguished from individuals, objects, and positions. We investigated a well-known configuration effect in spatial working memory to determine whether it could be derived from rational inferences applied to representations of individual objects. Specifically, we employed a spatial change detection task as in Jiang, Olson, and Chun (2000): participants remembered the positions of several identical objects and, at test, reported whether one item (' the probe', indicated with a bold outline) had changed position. Replicating earlier findings, performance was extremely poor when non-probe items occupied new, random positions in the test display, in comparison to conditions in which non-probe items maintained their previous positions or only the probe item appeared at test. These effects have been interpreted as evidence for configurations represented in SWM. In contrast, we hypothesized that they arise from an algorithm that identifies mutually exclusive correspondences among the memory and test items. Establishing correspondence is logically necessary for making comparisons between previous and current positions. Our algorithm identified correspondences via two assumptions known to operate in apparent motion: objects are more likely to make small as opposed to large position changes; and objects tend to sustain similar changes to one another. A rational model embodying these assumptions performed each of the experimental trials in multiple simulations under perceptual noise. When performance was averaged on a trial-by-trial basis, the model evidenced a strong and significant correlation with human performance (r2 = 0.90, 0.84, 0.69 for single item, preserved context, and new context conditions respectively), even reproducing severe biases observed in human behavior. These results highlight the inescapable role of correspondence algorithms in SWM, and one way that rational algorithms combined with simple inputs can produce complex dynamics.

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63.344 The ex-Gaussian analyses of reaction time distributions for visual working memory-based change detection under over-capacity setsizes Hyung-Bum Park[1](moonphb@gmail.com), Joo-Seok Hyun[1]; [1]Department of Psychology, Chung-Ang University

There are two predominant models of visual working memory (VWM) organization: one stipulates that VWM represents information into discrete slots and the other states that there is a single continuous pool of resources. However, one key aspect of the models has gone unnoticed, the speed of processing at the moment in-memory items should be assessed for their accuracy. Specifically, the slot model attributes incorrect memory performance for over-capacity memory setsizes to storage failure of test-relevant items, rather than failure of precisely storing items per se. According to this model, over-capacity memory assessment will be little hesitant regardless of setsize. Contrarily, the resource model attributes incorrect performance to setsize-dependent decline in the precision of in-memory items, although compensated by storing as many items as possible. Thus, the resource model expects that memory assessment eventually to be suffered as a result of an extensive coverage of imprecise in-memory items as setsize increases, consequently predicting proportional RT delays. To test this, we measured RTs in a change detection task across memory setsizes of 2, 4, 6, or 8 items. We model-fitted RT distribution from each setsize with an ex-Gaussian function under a maximum-likelihood method. We estimated three parameters from the Gaussian components, μ and σ (representing conventional central-tendency estimates) and from the exponential component, τ (representing a skewedness estimate), together providing a powerful comparison of the distributions across the setsizes. The analyses showed that the μ and σ were comparable across setsizes 4, 6, 8, except the lower μ and σ in setsize 2. The τ was constant regardless of setsize, indicating the distributions across over-capacity setsize conditions were virtually identical. The results suggest that about 4 items with good precision determined the changes detection performance, and support the slot model's idea that VWM represents information as a set of discrete high-resolution items.

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63.345 Effects of Emotion on Visual Working Memory Weizhen Xie[1](weizhen.xie@email.ucr.edu), Weiwei Zhang[1]; [1]Department of Psychology, University of California, Riverside

Emotional feelings modulate a wide range of cognitive processes. For example, negative emotion can narrow allocation of cognitive resources to encode memory with enhanced details. However, the nature of this focal enhancement of memory is unclear. Does this enhancement affect qualitative or quantitative aspects of memory? The present study investigated whether negative emotion modulated capacity (quantity) or resolution (quality) of visual working memory (VWM) representation, two independent limits on VWM storage. In a short-term color recall task, observers attempted to retain several colors in VWM over a 1-s retention interval and then recalled one of them by clicking on a continuous color wheel. On each trial, prior to the color recall task, one of three emotion conditions (negative, neutral, or positive) was induced with a gray-scale International Affective Picture System stimulus. Observers rated valence of the emotional stimulus on the Self-Assessment Manikin (SAM) scale. When negative emotion was induced, the subsequent VWM showed enhanced resolution compared to neutral and positive conditions. This effect was replicated for VWM using closed-contour shapes in Experiment 2. To isolate the stage of this effect, Experiment 3 adopted an iconic memory version of the color recall task by eliminating the 1-s retention interval. No significant enhancement in VWM resolution was observed. Because the involvements of perception, attentional, and iconic memory were comparable across Experiment 1 and 3, the selective enhancement of VWM resolution in Experiment 1 cannot be attributed to these factors prior to VWM encoding and maintenance. Taken together, the present results have demonstrated that negative emotion can selectively enhance resolution of internal representations in VWM, independent of VWM capacity, thus supporting the dissociable nature of quantity and quality in VWM.

63.346 Dissociating Contents of Consciousness from Contents of Short-Term Memory Thomas Alrik Sørensen[1,2](thomasalrik@gmail.com), Árni Gunnar Ásgeirsson[3], Camilla Funch Staugaard[3], Morten Overgaard[1,2]; [1]Centre for Cognitive Neuroscience, Aalborg University, [2]Cognitive Neuroscience Research Unit, CFIN, MindLab, Aarhus University, [3]Center for Visual Cognition, University of Copenhagen

The contents of consciousness and of short-term memory are hard to disentangle. As it seems intuitive that we represent attended objects in short-term memory and in experience, to many, it also seems intuitive to equate this content. Here we investigated memory resolution for orientation of a probed target in combination with a conscious evaluation of the experienced stimulus using the Perceptual Awareness Scale (PAS; Ramsøy & Overgaard, 2004). Observers were trained to report how they experienced a visual stimulus on a four-point scale representing their experience from "no experience" to a "clear experience" of a probed target. To assess memory resolution we used a Landolt-variation on the visual short-term memory (VSTM) resolution paradigm (e.g. Wilken & Ma, 2004). Set-sizes in the memory display were varied between 1, 2, or 4 elements. With increasing set-size we found that both the guessing parameter and the standard deviation increased, replicating patterns seen in more traditional paradigms using colors (see for example Bays, Catalao, & Husain, 2009). Moreover, we also find a decrease in guessing and standard deviation across PAS scores, showing that the resolution of content in VSTM is correlated with how it is consciously perceived by an observer. However, if we analyze the data across individual PAS scores and set-sizes, a different pattern emerges; across PAS scores we find that people are still affected by set-size in a systematic fashion. Controlling for target confusability we demonstrate that the effect cannot be explained by observers' responses to distractors, which leads us to conclude that contents of consciousness and VSTM may correlate, but are in fact not identical.

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Face perception: Emotions

Wednesday, May 21, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

63.401 Distinct Representations for Rigid and Non-Rigid Facial Movements in Face-Selective Regions of the Human Brain

Tessa Flack[1,2](tessa.flack@york.ac.uk), David Watson[1,2], Richard Harris[3], Mark Hymers[2], Andre Gouws[2], Andrew Young[1,2], Timothy Andrews[1,2]; [1]Department of Psychology, University of York, [2]York Neuroimaging Centre, University of York, [3]Psychosis Studies, Insitute of Psychiatry, Kings College London

Movements of the face play an important role in social communication. However, it is not clear whether there are distinct neural representations for different types of facial movement. In this study, we used fMRI to investigate the neural representations underlying changes caused by rigid and non-rigid movements of the face. In the first experiment, participants (n=83) viewed sequences of faces that varied in either facial expression (non-rigid change) or viewpoint (rigid change). Each sequence of images could be from the same identity or could contain different identities. Patterns of response were restricted to face-selective regions that were defined by the contrast face > scrambled face. Using correlation based MVPA, we found distinct patterns of response for facial expression and viewpoint within face-selective regions. A regression analysis showed that the patterns of response to expression and viewpoint were largely invariant to changes in facial identity and were consistent across participants. In the second experiment, we used an fMRI-adaptation paradigm to explore further the patterns of response to facial expression and viewpoint. Participants (n=31) viewed sequences of faces in which both expression and viewpoint were varied. We found adaptation to expression (lower responses in conditions when expression was unchanged) and adaptation to viewpoint (lower responses in conditions when viewpoint was unchanged) occurred in largely non-overlapping regions of the face-selective network. Together, these results reveal distinct topographic patterns of response for rigid and non-rigid movements in face-selective regions of the human brain. The segregation of regions involved in neural responses to changeable aspects of faces fits with the distinct social information that is conveyed by these different movements.

63.402 Characterizing the Manifolds of Dynamic Facial Expression Categorization

Ioannis Delis[1](ioannis.delis@glasgow.ac.uk), Rachael Jack[1,2], Oliver Garrod[1], Stefano Panzeri[1,3], Philippe Schyns[1]; [1]Institute of Neuroscience and Psychology, University of Glasgow, Glasgow G12 8QB, United Kingdom, [2]School of Psychology, University of Glasgow, Glasgow G12 8QB, United Kingdom, [3]Center for Neuroscience and Cognitive Systems @UniTn, Istituto Italiano di Tecnologia, Rovereto, Italy

Visual categorization seeks to understand how logical combinations of visual cues (e.g. "wide opened left eye" and "opened mouth") provide singly necessary and jointly sufficient conditions to access categories in memory (e.g. "surprise"). Such combinations of visual cues constitute the categorization manifold underlying the information goals of face categorization mechanisms and are therefore critical for their understanding. Yet, no method currently exists to reliably characterize the visual cues of the categorization manifold (i.e. its dimensions, such as "wide opened eyes" and "opened mouth") and how they combine (i.e. the manifold topology which dictates e.g. that "wide opened eyes" and "opened mouth" can be used independently or must be used jointly). Here we present a generic method to characterize categorization manifolds and apply it to observers categorizing dynamic facial expressions of emotion. To generate information, we used the Generative Face Grammar (GFG) platform (Yu et al., 2012) that selects on each trial (N = 2,400 trials/observer) a random set of Action Units (AUs) and values for their parametric activation (Jack et al., 2012). We asked 60 naïve Western Caucasian observers to categorize the presented random facial animation according to one of six classic emotions ("happy", "surprise", "fear", "disgust", "anger", "sad", plus "don't know"). For each observer, we used a Non-negative Matrix Factorization (NMF) algorithm to extract AU x Time components of facial expression signals associated with the pereceptual categorization of each emotion. We then performed a Linear Discriminant Analysis (LDA) to select the components (i.e. manifold dimensions) that discriminate between six emotion categories (Quian Quiroga and Panzeri, 2009; Delis et al., 2013). Hence, the dimensions of the resultant categorization manifolds represent the strategies observers use to categorize the emotions. Our data show that observers use multiple categorization strategies, which constitute the atomic signals of emotion communication via facial expressions.

63.403 Mental representations of emotional facial expressions are more complex rather than less accurate in older observers

Katarzyna Jaworska[1](k.jaworska.1@research.gla.ac.uk), Nicola J. van Rijsbergen[1], Steven W. McNair[2], Ioannis Delis[1], Oliver G.B. Garrod[1], Rachael E. Jack[1,2], Guillaume A. Rousselet[1], Philippe G. Schyns[1]; [1]Institute of Neuroscience and Psychology, University of Glasgow, 58 Hillhead Street, G12 8QB, Glasgow, United Kingdom, [2]School of Psychology, University of Glasgow, 58 Hillhead Street, G12 8QB, Glasgow, United Kingdom

The brain ages as dramatically as the body, manifesting itself in the reorganization of brain networks mediating interpretation of social signals. In particular, previous research has indicated that older adults are less accurate in categorizing negative facial emotional expressions, but the specific nature of these changes is unclear. Here, using the 4D Generative Face Grammar (GFG) platform (Yu et al., 2012) we generated a set of random combinations of facial movements, which coupled with reverse correlation informed the subsets constituting socially meaningful facial expressions. Eighteen young (10 female, median age=21, 18-25) and eighteen older (10 female, median age=65, 56-88) observers each categorized 4,992 animations of young and old faces into six basic emotions (i.e. 'happy', 'surprise', 'fear', 'disgust', 'anger', and 'sad') plus 'other/don't know', and rated the intensity of each expression (Jack et al., 2012). We then reverse correlated the random facial movements and their temporal parameters with the observers' responses. This resulted in dynamic models of the 6 basic facial expressions at five levels of intensity for each observer. We then performed a group-level k-means clustering analysis on the individual models. Young observers showed high homogeneity within expression categories, with a characteristic confusion between 'anger' and 'disgust'. Older observers showed well-preserved homogeneity for the expression models of 'disgust' and 'happiness'. By contrast, models of negative emotions ('fear', 'anger', 'sadness', and 'surprise') were less homogeneous across older observers. To examine whether this arose from a higher diversity of models of negative emotions in older observers, we identified the recognition strategies of each individual observer (Delis et al., submitted) and found that older observers deploy more strategies, in particular for models of 'sadness'.

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63.404 Recognition of complex and realistic facial expressions of emotion

Shichuan Du[1](du.64@osu.edu), Pamela Pallett[1], Aleix M. Martinez[1]; [1]Electrical and Computer Engineering, The Ohio State University

Everyday experience shows that naturalistic human facial expressions include complex combinations of signals, i.e., happily surprised or hate (which is a combination of anger and disgust). However, research in facial expressions of emotion has mostly been limited to the study of the prototypical expressions of happiness, surprise, anger, sadness, fear and disgust. This research has shown that human subjects can readily classify these expressions significantly above chance and that this recognition does not decrease even when the images are degraded (e.g., when the resolution of the image is systematically reduced). Here, we ask if this result holds for more realistic, everyday expression, e.g., when observing a facial expression of hate. Participants (n=14) performed an 8-alternative-forced-choice (8AFC) task while observing images of facial expressions of happily surprised, fearfully surprised, sadly angry, happily disgusted, angrily disgusted, awe, hate and neutral. Faces were shown in random order, without repetition, at five different image resolutions; from a high of 240x160 to a low of 15x10 pixels (see supplementary file). To prevent recognition based on previous exposure, an image shown at one resolution was not repeated at a different resolution. Exposure time was 500 ms, followed by a 750ms mask and the 8AFC semantic categorization task. Subjects performed significantly above chance for all categories. Most importantly, the categorization accuracy did not decrease until the images resolution was below 30x20 pixels. This result is consistent with previous experiments on the six prototypical facial expressions described earlier, where it was also observed that recognition stays relatively unchanged even for stimuli of only 30x20 pixels. These results hence suggest that our visual system can readily categorize facial expressions of many complex and naturalistic expressions, way beyond the classical six discussed in the literature.

63.405 Fearful facial expressions are salient to early visual processes: evidence from effective contrast analyses and continuous flash suppression. Nicholas Hedger[1](naah1g08@soton.ac.uk), Wendy J. Adams[1], Matthew Garner[1,2]; [1]School of Psychology, University of Southampton., [2]School of Medicine, University of Southampton.

Neurocognitive models suggest that threat-relevant stimuli are prioritised in human vision by a specialised visual pathway that operates independently of conscious awareness (Tamietto & de Gelder, 2010). Findings from paradigms such as backward masking and continuous flash suppression (CFS) suggest that unconsciously presented fearful faces gain prioritised access to attentional resources (e.g. Carlson & Reinke, 2008; Fox, 2002) and awareness (e.g. Sylvers, Brennan & Lillenfeld, 2011; Yang, Zald & Blake, 2007). We ask whether this 'fear advantage', is driven by (i) an evaluation of the threat relevance of stimuli, that operates without awareness, or (ii) low-level image properties (e.g. contrast). Using human contrast sensitivity data, we estimated the effective contrast of fearful, angry, happy and neutral face stimuli as the ratio of stimulus contrast to detection threshold, across spatial frequency (e.g. Baker & Graf, 2009). Effective contrast was modulated by expression, with fear having the highest effective contrast, and anger the lowest. Critically, this pattern of modulation was an excellent predictor of dominance in a CFS paradigm; fear faces broke suppression most frequently, whereas anger faces broke suppression least often. Further analyses show that the higher effective contrast of fear faces is stable across a range of viewing distances, particularly those characteristic of typical human interactions. Our analyses suggest that our fearful facial expression is optimised in terms of its salience to the low-level visual mechanisms of human observers. We re-evaluate the evidence for unconscious processing of threat in the context of these image analyses, via a meta-analysis of visual probe and rivalry studies that report a 'fear advantage'. Effective contrast provides a simple, alternative explanation for some existing reports of a 'fear advantage' that negates the need to invoke unconscious processes that are sensitive to threat.

63.406 Attentional effect on facial expression adaptation Pan Liu[1](pliu1@ntu.edu.sg), Hong Xu[1]; [1]Division of Psychology, Nanyang Technological University, Singapore

Previous studies have shown that attention can increase low-level adaptation (e.g., shapes). For high-level face adaptation, Rhodes et al. (2011) also found increased face identity aftereffects by attention. However, for facial expression adaptation, most studies focus on the necessity of awareness (e.g., Yang, et al., 2010; but Adams, et al., 2010) but not attentional modulation. In the current study, we investigated how task-driven attentional allocation modulates facial expression adaptation and examined the attentional shift via the microsaccade pattern. Three types of attentional allocation were included during adaptation: when the adapting sad face was shown right to the fixation cross for 2 s, participants had to count how many times a target appeared left to the fixation ("decreasing-attention condition"), or judge whether a brightness change occurred in the left or right part of the adapting face ("increasing-attention condition"), or do nothing ("free-attention condition"). A baseline condition without any adaptor was also included. The test face, randomly selected from a face set with varying facial expression from sad to happy, was presented at the same location as the adapting face for 200 ms. We found similar facial expression aftereffects in free-attention and increasing-attention conditions. This indicates no enhancement on facial expression adaptation by increasing attention to the adapting face. However, these aftereffects were both significantly larger than that in the decreasing-attention condition (both p's <.05). This suggests decreasing attention to the adaptor reduces facial expression adaptation. Therefore, we found asymmetric attentional modulation effects on facial expression adaptation. Moreover, eye movement pattern analysis revealed more right-oriented microsaccades in both free-attention and increasing-attention conditions than those in the decreasing-attention condition (both p's <.05). This provides evidence for the attentional shift and further supports the behavioral findings. Taken together, our current findings provide new insights for the top-down mechanism in facial expression adaptation.

63.407 Is He Afraid or Looking at a Spider? Visual Attention to Facial Expressions Varies With the Task Nicole Nelson[1](nnelson@brocku.ca), Catherine Mondloch[1]; [1]Psychology, Brock University

In daily life, we must interpret others' facial expressions within a given situation, but in the lab, participants are often asked to assign a label to isolated expressions. We showed participants the same set of emotional facial expressions in two different tasks to investigate whether performance on these tasks draws on different styles of visual processing. Participants (N=38) viewed slides comprised of one facial expression and three emotional scenes (Figure 1) presented on a Tobii eye-tracker. Twenty-four posers each contributed one expression to the slides (happiness, anger, fear, disgust) and scene triads were built from 12 emotion-related scenes. In Matching trials, participants viewed each slide and verbally indicated which scene matched the expression. In Labeling trials, participants viewed each slide again and provided a label for each expression. We examined three areas of interest: eyes, mouth, and nose/central face. Our DVs were the number of times and length of time that participants looked to each AOI; to control for participants' longer looking time when labeling expressions, we calculated each DV as a percentage of overall looking to the face. Task x AOI interactions (ps <.001) showed that participants looked longer and more often to the nose/central face during Matching trials than Labeling trials (ps <.001). Conversely, participants looked longer and more often to the eyes during Labeling trials than Matching trials (ps <.001). This pattern replicated for all emotions but happiness (Figure 2), as shown by Task x AOI x Emotion interactions (ps <.001). These data show that participants' allocation of visual attention varied with the task presented. Tasks in which participants must assign labels to expressions may overestimate the importance of the eye region, while underestimating the importance of the nose/central face region, which appears to be important in participants' matching of expressions to situations.

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63.408 Neural Responses to Object Priming of Fearful and Happy Facial Expressions Bonnie Heptonstall[1](bonniehe@uvic.ca), Marilyn Thorpe[1], Buyun Xu[1], James Tanaka[1]; [1]Department of Psychology, University of Victoria, British Columbia

Facial expressions are not perceived in isolation, but are embedded in a complex perceptual and social environment. Contextual factors, such as body gesture and emotional scene, have been shown to influence the processes of expression recognition. However, it is not known how affective objects influence the underlying neural mechanisms related to how facial expressions are recognized. To explore this question, event related potential (ERP) responses to emotionally primed expressions were recorded. Participants viewed a person with a neutral expression being presented with a positive emotional object (money, birthday cake), or a negative emotional object (spider, gun). The objects appeared at one of two stimulus onset asynchronies (SOA) (0 ms and 500 ms). Following the SOA interval, the neutral expression of the person changed to a happy or a fearful expression. After 1000 ms delay, participants categorized the expression as either "happy" or "fear". The main finding was that "happy" faces elicited a greater positive amplitude around 300 to 350 ms when primed with a positive object (e.g. birthday cake) than when primed with a negative object (e.g. spider). Interestingly, this congruency effect was not found for "fear" faces. Taken together, these results suggest that single objects with strong emotional associations can influence how the brain processes positive facial emotions.

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63.409 Enhancing facial emotion recognition with tACS induced gamma oscillations Agnieszka Janik[1](a.janik@gold.ac.uk), Tirta Susilo[2], Constantin Rezlescu[3], Michael Banissy[1]; [1]Department of Psychology, Goldsmiths University of London, UK, [2]Department of Psychological and Brain Science, Dartmouth College, USA, [3]Department of Psychology, Harvard University, USA

In recent years numerous studies documented a key role of neural oscillations in perception and cognition. However, surprisingly little is known about oscillatory activity underlying facial affect recognition. The limited number of studies that addressed this question indicate that gamma oscillations are one key mechanisms underlying this process. The present study aimed to further elucidate the role of neural oscillations within the gamma range in facial emotion recognition in healthy adults by using transcranial alternating current stimulation (tACS) to transiently modulate cortical oscillations while participants completed facial affect and facial identity tasks. In Experiment 1, participants (N= 24) completed a same-different emotion recognition task while tACS in the beta range, gamma range, or sham stimulation was delivered over the visual cortex. Statistical analysis revealed that gamma stimulation resulted in greater accuracy scores. In Experiment 2, participants (N =22) completed two tasks; one examining facial emotion perception and another examining facial identity perception (Cambridge Face Perception Task, CFPT). The first task entailed sorting pictures of the same individual from the least to most angry (faces were morphed between neutral and angry faces in order to contain varying levels of anger). The

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CFPT required participants to sort pictures of faces according to a degree of similarity between a target face and six images that were morphed between the target face and another person. Each participant completed these tasks twice, while tACS within the gamma range or sham stimulation was delivered. Modulating occipital gamma facilitated processing of facial affect, but did not influence participants' performance on the CFPT. Therefore, delivering tACS in the gamma band via electrodes placed over primary visual cortex selectively enhances facial affect, but not identity recognition.

Acknowledgement: Economic and Social Research Council

63.410 **Brain Networks for the Categorization of Facial Expressions of Emotion** Aleix Martinez[1](aleix@ece.osu.edu), Shichuan Du[1], Dirk Walther[1]; [1]The Ohio State University

Different regions of interest (ROI) of the brain have been hypothesized to encode distinct emotion categories, most notably the amygdala in fear and sadness, the insula in disgust, the nucleus accumbens in anger, and the cingulate in happiness. An alternative model hypothesizes that the hippocampus and the postcentral gyrus encode these five emotion categories plus surprise. Each brain lesion, traumatic event and psychiatric disorder favors one of these models. We explore 33 hypothesized ROI with MVPA and show that most hypotheses hold true. Most categories are in fact consistently and differentially represented in multiple regions of the brain, suggesting there is a large network of areas responsible for the analysis and categorization of facial expressions of emotion. For example, happiness is consistently and differentially represented in the cingulate, hippocampus, postcentral gyrus, frontal pole, amygdala, thalamus and insula to name but a few, sadness in the parahippocampal gyrus, temporal pole, and superior temporal gyrus among many others. More specifically, we examined the brain activation patterns of 24 subjects using fMRI. During the scan, participants viewed samples of these six categories of facial expressions plus neutral. Each facial expression was displayed by 120 faces with distinct identities. The experiment consisted of ten 6-min runs. Each run had fourteen 12.5s face blocks alternating with fifteen 12.5s resting and fixation periods. A passive viewing paradigm was used on half of the subjects while a two-alternative-force-choice task was given to the other half. We applied Linear Discriminant Analysis in 33 hypothesized ROI. Significant classification accuracies ($p<0.05$) were obtained for the hypothesized emotion versus the other emotions in most ROI. To conclude, our results support the notion that categorical representation of these six emotion categories resides in a large network of brain areas and further suggest that this information is not uniformly distributed in the networks.

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63.411 **Facial expression recognition takes longer in the posterior superior temporal sulcus (pSTS) than in the occipital face are (OFA)** David Pitcher[1](david.pitcher@nih.gov); [1]National Institute of Mental Health

Recognizing facial expressions is essential for everyday social interaction but our understanding of how the brain performs this task is limited. Neuroimaging studies have identified a face-selective region in the right posterior superior temporal sulcus (rpSTS) that responds more to facial expressions than to facial identity but precisely when the rpSTS begins to causally contribute to expression recognition is unknown. The present study addressed this issue using transcranial magnetic stimulation (TMS). In Experiment 1 repetitive TMS delivered over the rpSTS, at a frequency of 10Hz for 500ms, selectively impaired a facial expression task but had no effect on a matched facial identity task. In Experiment 2, double-pulse TMS (dTMS) was delivered over the rpSTS or over the right occipital face area (rOFA), a face-selective region in lateral occipital cortex, at different latencies up to 210ms after stimulus onset. Task performance was selectively impaired when dTMS was delivered over the rpSTS at 60-100ms and 100-140ms. dTMS delivered over the rOFA impaired task performance at 60-100ms only. These results demonstrate that the rpSTS causally contributes to expression recognition and that it does so at the same latency as the rOFA but over a longer time-scale. The difference in length of the TMS induced impairment between the rpSTS and the rOFA further suggests that the neural computations that contribute to facial expression recognition in each region are functionally distinct.

63.412 **Continuous and Categorical Patterns of Neural Response to Facial Expressions in Face-Selective Regions of the Human Brain** Mladen Sormaz[1,2](ms930@york.ac.uk), Andrew W Young[1,2], David M Watson[1,2], Timothy J Andrews[1,2]; [1]Department of Psychology, University of York, UK, [2]York Neuroimaging Centre, UK

The ability to perceive facial expressions of emotion is essential for effective social communication. However, the way that facial expression is represented in the brain remains controversial. Opposing models have proposed that the perception of facial expression is based on either a continuous or a categorical representation. In this study, we explored whether patterns of neural response in face-selective regions had continuous or categorical properties. Twenty-nine participants viewed images of facial expressions of five basic emotions (fear, anger, disgust, sad, happiness) in a fMRI block design. Face-selective regions were defined using an independent localizer scan. Patterns of response to different facial expressions were analysed using correlation based MVPA. To determine whether the patterns of response in face-selective regions involved continuous or categorical representation of facial expression, we compared the neural patterns of response with the pattern of behavioural response on tasks which involved either categorical or continuous perceptual judgements. The patterns of behavioural response from the continuous and categorical tasks were used as predictors in a multiple regression analysis. We found that the response to different facial expressions across all face-selective regions considered together was best fitted by a continuous rather than a categorical representation. However, when we explored the pattern of response in different subdivisions of the face-selective network it was clear that some regions (e.g. superior temporal) had a more continuous pattern of response to facial expressions, whereas other regions (e.g. inferior frontal) had a more categorical response. These results offer a novel demonstration that both continuous and categorical representations of facial expression underlie our ability to extract this important social cue.

63.413 **Hemispheric differences in visual strategies used in facial expression categorization** Karolann Robinson[1](robk11@uqo.ca), Jessica Royer[1], Caroline Blais[1], Daniel Fiset[1]; [1]Département de psychoéducation et de psychologie, Université du Québec en Outaouais

Decoding facial expressions of emotions is a crucial ability for successful social interactions. However, little is known about the specific contribution of each cerebral hemisphere in the visual mechanisms underlying successful facial expression categorization. Here, we investigated interhemispheric differences in visual information use in the recognition of a subsample (i.e., anger, fear, disgust and happiness) of basic facial expressions, i.e. the type and quantity of information required for efficient categorization. The present study used the Bubbles technique (Gosselin & Schyns, 2001) to verify whether visual strategies in facial expression categorization differed between hemispheres. Sparse versions of emotional faces were created by sampling facial information at random spatial locations and at five non-overlapping spatial frequency bands. The average accuracy was maintained at 62.5% (halfway between chance and perfect performance) by adjusting the number of bubbles on a trial-by-trial basis using QUEST (Watson & Pelli, 1983). Fifteen participants (3 men; Mage = 23.13; SD = 3.04) each categorized 2200 sparsed stimuli that were either presented in central or peripheral vision (2.5° of visual angle away from the central fixation cross). Overall classification images (we summed the five spatial frequency bands) showing what information in the stimuli correlated with participants' accuracy were constructed separately for each emotion and presentation location by performing a multiple linear regression on the bubbles locations and accuracy. A pixel test was applied on the classification image to determine statistical significance (Zcrit=3.36, $p<0.05$; corrected for multiple comparisons). Our results indicate that different facial regions were used by the left and right hemisphere in the categorization of fearful and angry faces, but not for happy and disgusted faces. These findings suggest that each hemisphere successfully uses different visual information while processing some of the basic emotions expressed by faces.

63.414 **From the eyes to the rest of the face in visual cortex: Decoding facial expressions of emotion across non-overlapping face feature information** Fraser Smith[1](Fraser.Smith@uea.ac.uk), Derek Mitchell[2], Steven Greening[3]; [1]School of Psychology, University of East Anglia, [2]Brain & Mind Institute, University of Western Ontario, [3]University of Southern California

We recently showed (Smith & Goodale, 2011, VSS) that early visual and lateral occipital regions contain a rich amount of information about facial emotion categories. We observed reliable decoding that generalized across entirely different face sets, and found a reliable correlation with human

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behaviour independent of low level features (V1 model), suggesting that top down influences might be implicated in the implicit processing of facial expressions. In the present work we test more directly the role of top down influences in modulating processing of facial emotions in visual cortex. We reanalysed data previously partially published (Han et al. 2012) where participants performed an explicit emotion categorization task (5AFC – happy, fear, disgust, anger and neutral) in a rapid event related fMRI experimental protocol. Faces were presented either as whole faces, eyes only or rest of face without the eyes, thus providing two stimulus conditions where there was no overlap in the actual visual information presented (eyes only; rest of face minus eyes). We show that decoding of facial expressions is possible in early visual, face selective (FFA&OFA) and also frontal brain regions (prefrontal cortex plus inferior frontal gyrus). Strikingly, we find that successful decoding of emotion generalizes across entirely non-overlapping sets of presented visual information in occipital cortex (i.e. train eyes only and test rest of face, or vice versa). This suggests that feedback to early parts of visual cortex can be of a very rich nature: even allowing for reactivation of representations of non-presented parts of a stimulus, to aid in successful categorization (see Smith & Muckli 2010; Petro, Smith et al 2013).

63.415 **Impact of task demands and fixation to features on the time course of facial emotion processing** Karly Neath[1](kneath@uwaterloo.ca), Roxane Itier[1]; [1]University of Waterloo

The time course of facial emotion processing remains debated. Recent studies have suggested that facial features specific to an emotion are critical for accurate facial emotion discrimination. We investigated whether fixating on these diagnostic facial features impacted the time course of facial emotion processing and whether this varied as a function of task. ERPs were recorded in response to presentations of fearful, joyful or neutral faces while fixation was restricted to the left eye, right eye, nose or mouth using an eye-tracker. In the explicit emotion discrimination task, emotion only impacted the Early Posterior Negativity (EPN) (230- 250ms post-stimulus) that was largest for fearful faces, followed by happy, and smallest for neutral faces. In the oddball detection task where participants responded to flower target images, fearful and neutral faces elicited larger responses than happy faces on the P1 component (80- 130ms post-stimulus); fearful faces also elicited larger responses than neutral faces on the face-sensitive N170 component (120-220ms post-stimulus), but no modulation by emotion was seen on the EPN. In addition, in both tasks, the N170 was larger for fixation to the left and right eye compared to the nose and mouth regardless of facial emotion. Thus, fixation on diagnostic features did not impact the time course of emotion processing but the N170 response to eyes suggests the involvement of an eye-detector in the face structural encoding stages. Results also suggest earlier processing of emotion in expression-irrelevant compared to expression-relevant tasks.

63.416 **Matching emotional expressions of faces within an olfactory context: Does my own feeling matter?** Arnaud Leleu[1](arnaud.leleu@u-bourgogne.fr), Caroline Demily[2,3,4], Nicolas Franck[2,3,4], Karine Durand[1], Jean-Yves Baudouin[1], Benoist Schaal[1]; [1]Centre des Sciences du Goût et de l'Alimentation – UMR 6265 CNRS – UMR 1324 INRA – Université de Bourgogne, Dijon, France, [2]Centre de Neuroscience Cognitive – UMR 5229 CNRS, Bron, France, [3]Centre Hospitalier Le Vinatier, Bron, France, [4]Université Claude Bernard Lyon 1, Lyon, France

The ability to recognize facial expressions may imply the matching between self-produced emotions and those perceived in others. To investigate this issue, we designed two experiments in which participants had to match the emotion expressed by a centrally-presented face with one of the expressions (anger, disgust, fear, happiness, sadness, neutral) displayed in smaller-sized lateral photographs. Three olfactory contexts (neutral, aversive, pleasant) were used to elicit various moods or feelings during the task. To evaluate whether the odorants modulate the detection thresholds of the expressions, morphs were made between neutrality and all other emotions (every 10%, from 0% to 100%), and the central face expressed the different intensities along these continua. In experiment 1, a perceptual task was performed with no indication on the expressed emotion. In experiment 2, the task combined perceptual and verbal information with corresponding emotions labeled under each lateral face. In both experiments, results indicated that happiness was detected at lower intensities with the pleasant odorant. The inverse bias (i.e., lower detection thresholds with the aversive odorant) was found for anger in experiment 1 and for disgust in experiment 2, presumably because anger was confounded with disgust when no labels were displayed. Interestingly, the overall number of intrusions (i.e., false recognitions) was enhanced with the pleasant odorant in experiment 1, suggesting that this odor reduced the perceived differences between the four categories of negative emotions when no verbal information was delivered. In experiment 2, intrusions for anger and disgust were modulated in opposite directions by the aversive odor (i.e., more intrusions for anger, less for disgust). Taken together, these findings indicate that the emotional correlates of odor perception can facilitate the detection of facial expressions with congruent hedonic value.

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63.417 **Sight sublimated by odors: effect of subliminal odors on facial emotion detection.** Nicolas Dollion[1](dollionnicolas@gmail.com), Jean-Yves Baudouin[1], Karine Durand[1], Benoist Schaal[1]; [1]Centre des Sciences du Goût et de l'Alimentation, CNRS (UMR 6265), Université de Bourgogne, Dijon, France

Our perception and cognitive integration of the environment are based on multisensory processes. Thus, all sensory-perceptual systems reciprocally influence each other. This is also true for the less-studied olfactory sense, which has repeatedly been shown to modulate visual exploratory behavior. For example, when they explore a complex visual scene adult subjects orient their gaze more rapidly and for shorter duration to the stimuli that are congruent, rather than incongruent, with the odor context (Seigneuric et al., 2010). Such an odor-based visual bias can be mediated by emotional processes, as the valence of odors can modulate how efficiently facial expressions are processed (e.g., Leppänen & Hietanen, 2003). So far, only few studies have assessed whether and how odorants administered at subliminal levels affect visual processing. In this study, odorants chosen to be hedonically contrasted (i.e. strawberry and Butiric Acid) were delivered at subliminal levels to evaluate whether they modulate the ability to detect facially-expressed emotions. Participant's detection threshold for both odorants was first measured using a single ascending staircase procedure with a triple forced-choice. Then, while exposed or not to a subliminal odor, they were required to visually detect an emotional target, in determining whether an expressive face (i.e. expressing anger, disgust, fear, joy or sadness) was present in an array of 6 faces among which 5 were neutral. During the detection task, different oculometric parameters were collected (e.g., emotional target and distractors treatment time, target fixation latency, etc.). It came out that the odors influence different oculometric parameters. In sum, the present findings confirm that odors delivered below threshold can modulate visual search for emotional faces, and clarify its different effects on visual exploration for facial expressions.

63.418 **Perceiving "face space"** Sean F. O'Neil[1](seano@unr.edu), Amy Mac[1], Michael A. Webster[1]; [1]Department of Psychology, University of Nevada, Reno

The neural coding of faces is typically assumed to reflect a norm-based ¨face space¨ in which individual faces are represented by how far and in what direction they differ from the average. We asked to what extent observers have cognitive access to the metrics of this space. To explore a space with limited and well-defined dimensions, stimuli were restricted to basic expressions and their antifaces for a common average identity, with all faces created with FaceGen Modeller. Individual faces spanned different directions and magnitudes within planes defined by two different expressions and their anti-expressions. In one case we tested how well observers could identify the opposite direction or ¨antiface¨ of a given face within each plane. Observers were presented with a reference face angle in the plane and asked to select its opposite angle. Some pairs produced choices reflecting conceptual associations (e.g. sad is the opposite of happy), and configural shape opposites were sometimes also selected, yet in general the settings showed little clear bias toward the angular opposite. Most observers were consistent in their settings, while responses across observers were idiosyncratic. In a second experiment, observers adjusted the magnitude of a test expression until it matched a reference face's expression intensity. Both face/antiface pairs and different-expression pairs were used. Settings could be made reliably for some expressions but did not always increase consistently or monotonically with reference intensity. Together these results suggest that although the neural representation of faces may reflect the geometry of a space, we are not in general able to consciously access this geometry to infer the metrical relationship between different facial configurations.

Acknowledgement: Supported by EY-10834

63.419 **Beyond the basics: Facial expressions of compound emotions** Pamela Pallett[1](pallett.1@osu.edu), Aleix Martinez[1]; [1]Department of Electrical and Computer Engineering, The Ohio State University

Everyday experience suggests we are able to produce and visually distinguish a large number of facial expressions of emotion. Yet, to date, most studies have focused on a small set of emotion categories: happiness, sur-

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prise, anger, sadness, fear and disgust. Combining or compounding these emotion categories generally results in rich, complex and meaningful social, affective and communicative expressions, e.g., the facial expression of happily surprised and the facial expression of angrily surprised. Here, we evaluate which facial expressions of compound emotions can be correctly labeled semantically, as well as quickly and accurately visually discriminated from other facial expressions of emotion. Stimuli included 15 facial expressions of compound emotions, the 6 typically studied emotions and a neutral face. In Experiment 1, participants made ranked-order judgments of the emotions displayed in each face. Any of combination of the six traditional emotions or neutral could be selected. For example, if Awe contains both surprise and fear, with a greater contribution of surprise, then participants should select Surprise first, then Fear and no other emotions. Data were analyzed using a single-winner election method for ordinal ranked data (Schulze method); this provided a ranked list of emotion labels for each facial expression. In Experiment 2, subjects completed a 3-alternative forced choice delayed match-to-sample task, in which a target facial expression of emotion was selected from a set of three test face emotions (1 compound emotion and 2 corresponding standard emotions). Data were analyzed using a Wilcoxon signed-rank test with Bonferroni correction. Results show that at least seven (and possibly twelve) common facial expressions of compound emotions are consistently and accurately categorized (i.e., semantically labeled and visually discriminated) by observers. These results suggest that the repertoire of facial expressions readily recognized by observers and employed by our cognitive and affective systems is larger than previously thought.

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63.420 **The effect of contrast negation on real/artificial face discrimination** Christopher Tonsager[1](tonsager.chris@gmail.com), Benjamin Balas[1]; [1]Psychology, North Dakota State University

In general, observers can reliably distinguish between real faces and computer-generated (CG) faces. Previous results suggest that observers rely heavily on eye appearance to categorize faces as real or artificial. We examined how eye appearance affects real/CG face categorization by using contrast negation to selectively disrupt local feature appearance. Negation severely disrupts face processing, so we expected that real/CG categorization would be impaired following the negation of critical features. Critically, we generated "contrast chimeras" (images in which the contrast polarity of the eyes differs from the rest of the face) to determine how task performance was affected by eye appearance relative to the rest of the face. In two experiments, we used a simple discrimination task to measure real/CG categorization. Our stimuli were comprised of photographs of real men and women and CG faces created from the original photographs. In both experiments, participants viewed a real face and a CG face sequentially on each trial and were to identify which image depicted a real person. In Experiment 1 (N=16), observers completed this task using the original images and fully contrast-negated faces. In Experiment 2 (N=21), participants viewed positive and negative images, as well as "contrast chimeras" depicting either negative eyes in a positive face or vice-versa. In all cases, image presentation time was 500ms with a 750ms ISI. We observed a main effect of contrast polarity on performance in Experiment 1 ($p<0.05$), demonstrating that real/CG categorization is disrupted by negation. In Experiment 2, we observed no significant effect of eye polarity ($p=0.14$) on accuracy, but did find that negating the rest of the face did significantly lower accuracy ($p=0.02$). We conclude that real/CG face categorization may depend less upon eye appearance than prior reports suggest, and that the appearance of the skin may be a highly diagnostic cue.

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Spatial vision: Neural mechanisms

Wednesday, May 21, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

63.421 **Separating neuronal suppression from hemodynamic suppression** Pinglei Bao[1](pbao@usc.edu), Chris Purington[3], Bosco S. Tjan[1,2]; [1]Neuroscience Graduate Program, University of Southern California, [2]Department of Psychology, University of Southern California, [3]Vision Science Graduate Group, University of California, Berkeley

When stimuli are presented closely in time or space, the total evoked neuronal response is often less than the sum of responses evoked by each of the stimuli alone. Similar suppression is observed in fMRI BOLD signal, which has been attributed to neuronal origins. However, the suppression effect can also be due to nonlinearity in the hemodynamics, devoid of any neural correlates. We conducted two experiments with a subject who was born without an optic chiasm. The achiasmic subject's left and right visual hemifield representations are overlaid in both cerebral hemispheres. At each point in V1-V3, there are two population receptive fields (pRFs) situated symmetrically across the vertical meridian. These pRFs do not interact. For example, a high-contrast static or counter-flickering mask presented contralateral to a contrast-detection target has no effect on detection threshold. In one experiment, we measured the net BOLD response to a high-contrast peripherally presented stimulus that flashed twice with a 1 sec ISI. Subtracting the single-flash response from the net response yielded the second-flash contribution, which in V1 was 31% less than the single-flash response. However, a similar amount of suppression (28%) was observed when the second flash was presented to the visual hemifield contralateral to the first flash. Hence, less than 1/10 of the observed 31% suppression (an insignificant amount) can be attributed to a neuronal origin. In a second experiment, we found that a high-contrast spatial surround led to 100% suppression of a low contrast center in V1 when both center and surround were presented to the same hemifield. When the surround and center were presented to different visual hemifields, we observed 68% suppression of the center. Thus, only 1/3 of the observed suppression in the conventional surround suppression setup can be attributed to a neuronal origin. In both experiments, non-neuronal hemodynamic suppression dominated.

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63.422 **The pattern of spontaneous visual cortex activity is not altered by callosotomy or extrastriate lesion** Geoffrey Karl Aguirre[1](aguirreg@mail.med.upenn.edu), Omar Butt[1]; [1]Department of Neurology, University of Pennsylvania

Spontaneous "rest" fMRI signals have a spatial correlation structure in retinotopic visual cortex that resemble the radial organization of eccentricity and the hierarchical connectins of visual areas. The neural mechanism of this synchronized activity is unknown. We tested two hypotheses regarding the generation of resting state signals: First, does the corpus callosum mediate inter-hemispheric synchronization of fine-scale signals? Second, does eccentricity-selective feedback from high extrastriate cortical regions produce the gradient of correlation aligned with eccentricity? We obtained BOLD fMRI data at 3T while subjects rested with their eyes closed in darkness. 22 controls subjets contributed 8 minutes of data. Additionally, we studied a 54 year-old who underwent a total callosotomy 12 years prior for treatment of epilepsy (72 minutes), and a 48 year-old who underwent surgical resection of a right fusiform glioma 2 years prior (16 minutes). All data were transformed to cortical surface space (fsaverage sym). Volumetric digital lesion healing was conducted for the brain lesion patient prior to transformation to preserve cortical topology. We compared regional and fine-scale resting state patterns between the two patients and the mean and standard devation (SD) of the population of controls. Generally, we found that the patients were very similar to the control group. Measures of fine-scale correlation width and ampliude (Butt 2013, J Neurosci) were all within one SD of the control group mean. Regional, inter-hemispheric correlations were relatively reduced in both patients, but still within 1-2 SDs of the controls. Despite dramatic alterations of neuroanatomy, we found that our two patients had regional and fine-scale spontaneous activity within visual cortex that could not be distinguished from that of a control subject. These results place constraints upon the possible generative neural sources of resting state signals.

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63.423 **Local density of human midget retinal ganglion cell receptive fields** Andrew Watson[1](andrew.b.watson@nasa.gov); [1]NASA Ames Research Center

The midget retinal ganglion cells of the human retina are thought to underly spatial pattern vision, and as such the spacing of their receptive fields imposes a fundamental limit on human visual spatial resolution. This spacing varies across the retina and increases rapidly with distance from the fovea. Modeling visual processing of extended or peripheral targets requires a quantitative description of this spacing across the visual field. Curcio and colleagues have provided estimates of the local density of cones (Curcio, Sloan, Kalina & Hendrickson 1990) and retinal ganglion cells (Curcio and Allen, 1990), as well as estimates of centrifugal displacements of foveal ganglion cells from their receptive fields (Drasdo, Millican, Katholi & Curcio, 2007), all in the same set of human retinas. In addition, Drasdo and Fowler (1974) have provided a model human eye that allows nonlinear mapping from anatomical coordinates in mm to visual field coordinates in degrees. We have combined these results (and a few plausible assumptions), to produce a new formula for midget retinal ganglion cell spacing as a function of position in the monocular or binocular visual field. The new formula does not depend on psychophysical results, extends to the full range of eccentricities, and is not confined to the four principal meridians. It is consistent with recent estimates of letter acuity for five observers viewing targets under adaptive optics conditions (Rossi and Roorda, 2010).

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63.424 Reduced visual orientation-surround suppression in schizophrenia shown by measuring contrast detection thresholds

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The contrast detection threshold for a grating located in the visual periphery is increased by the presence of a surrounding grating of the same spatial frequency and orientation. This inhibition has been termed orientation-surround suppression. Previous studies (Yoon et al., 2009, Schizophrenia Bulletin, 35,6) using contrast discrimination thresholds, have suggested abnormal surround suppression in patients with schizophrenia. In this work, we have tested this hypothesis by measuring contrast detection thresholds using different stimulus configuration (Serrano-Pedraza, Grady, & Read, 2012, Journal of Vision, 12(6)). We tested two groups: 21 patients with schizophrenia and 44 healthy control subjects. To obtain the contrast thresholds, we used Bayesian adaptive staircases in a 4AFC detection task where the target was a grating within a 3 deg Butterworth window that could appear in one of four possible positions at 5 deg eccentricity. We compared three experimental conditions, a) target with no surround (NS), b) target on top of a surrounding grating of 20 deg diameter and 25% contrast with same spatial frequency and orthogonal orientation (OS), and c) target on top of a surrounding grating with parallel (same) orientation (PS). Our results show significantly lower thresholds for controls than for patients in NS and OS conditions (t-test, $p<0.001$). We also found significant differences between groups when comparing suppression ratios PS/NS of contrast thresholds ($p<0.001$). To examine whether the difference in PS/NS was driven by the lower NS thresholds for controls, we also examined a subgroup chosen such that patients and controls had similar NS thresholds. This subgroup showed significant differences between patients and controls in both PS ($p=0.0167$) and PS/NS ($p=0.0105$). Both these analyses therefore indicate that a parallel surround raised contrast thresholds less in patients than in controls. Our results support the hypothesis that inhibitory lateral connections in early visual cortex are impaired in schizophrenia patients.

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63.425 The impact of psychological stress on the contrast sensitivity function

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It has been shown that stress modifies the allocation of attentional resources such that the perceptual field is narrowed (Staal, 2004), and that attention modulates early visual mechanisms such as contrast sensitivity (Carrasco, Penpeci-Talgar, & Eckstein, 2000). Here, we investigated whether social stress has an impact on the sensitivity to different spatial frequencies. We used the method of limits to estimate the contrast sensitivity function (CSF) of nine participants after having submitted them to a socially stressful or a control condition. In the stress condition, participants underwent the Trier Social Stress Test for Groups (TSST-G; Von Dawans, Kirshchbaum & Heinrichs, 2011), a standardized laboratory stressor. The control condition was identical to the TSST-G condition save for the socioevaluative threat component. The CSF task consisted of 60 trials in which participants adjusted the contrast of a Gabor patch composed of one of 6 spatial frequencies (0.6, 1.2, 2.4, 4.8, 9.6, and 19.2 cpva) until they detected its presence. The number of trials was kept low to ensure that the stress manipulation was effective throughout the CSF measurement (salivary cortisol was measured 7 times during the experiment). To compensate, we resampled the 126 possible combinations of 5 participants, and performed a sign test to compare the contrast sensitivity (1/threshold) across the two experimental conditions. Our results show that social stress alters the CSF, reducing sensitivity to low-to-medium spatial frequencies (for 0.6 to 4.8 cpva, inclusively), and maximum contrast sensitivity (423.45 vs. 452.63). Moreover, our curve-fitted results indicate a shift of peak sensitivity toward higher spatial frequencies (6.63 vs. 4.8 cpva), and a slight narrowing of the FWHM (4.3 vs. 4.45 octaves), induced by stress, all p's<.001. Potential implications for higher-level visual tasks such as emotion recognition will be discussed.

63.426 Impact of pulvinar on contrast response functions in the primary visual cortex

Christian Casanova[1](christian.casanova@umontreal.ca), Jimmy Lai[1], Sébastien Thomas[1]; [1]Visual Neuroscience laboratory, School of Optometry, Université de Montréal

The pulvinar, the largest extrageniculate thalamic visual nucleus, establishes reciprocal connections with virtually all the visual cortical areas of the brain. The pulvinar is thus in a strategic position to influence different levels of cortical processing through “driver” or “modulatory” synapses. It is generally considered that, in all species, projections from the pulvinar to the primary visual cortex (V1) are modulatory, altering decoding properties of neurons without changing their basic receptive field properties. Results from our laboratory, based on optical imaging responses evoked by electrical stimulation, support this assumption to some extent (Vanni et al. 2011, Soc. Neurosci. Abstr.). We further investigated this issue by recordings cells in V1 during the reversible inactivation of the lateral posterior nucleus (LP) - pulvinar complex in the cat. Neurons in V1 were recorded before, during and after the inactivation of the striato-recipient zone of the LP-pulvinar complex with microinjections of GABA. Recording and injection electrodes were positioned such that thalamic and cortical receptive fields overlapped. No change in the preferred orientation or direction selectivity of V1 neurons was observed during pulvinar inactivation. However, for a majority of the cells tested (n=39/58), the response amplitude to the optimal stimulus was reduced by a mean of 66%. The contrast response function of neurons was modeled with the Naka-Rushton function: Rmax(Cn/Cn+Cn50)+b. Analysis of the effects of pulvinar inactivation on the contrast response function of V1 cells revealed the existence of at least three types of modulation. These modulations were classified according to the predominantly affected curve parameter: Nine cells exhibited a decrease in Rmax, five cells had an increase in the exponential factor (n), and four units had a C50 increase. These results indicate that the pulvinar can modulate the activity of V1 neurons by modifying the profile of their contrast response function.

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63.427 A multi-pronged approach to identifying functional subdivisions of the human pulvinar

Jason Fischer[1](jason_f@mit.edu), Nancy Kanwisher[1]; [1]Department of Brain and Cognitive Sciences and McGovern Institute for Brain Research, Massachusetts Institute of Technology

The pulvinar nucleus of the thalamus is well-positioned to play an integrative role in vision, owing to its widespread connections with the visual cortex. However, the precise function of the pulvinar remains elusive, and likewise, its functional organization is still poorly understood. Here we adopted a multi-pronged approach to uncovering functional subdivisions within the human pulvinar. We collected fMRI data during resting state (in the absence of visual input or a task), and, separately, while subjects performed an object discrimination task designed to test the position selectivity of visual responses in the pulvinar. Within the resting state data, we used k-means clustering to parcellate the pulvinar into subregions with distinct resting signals. We then tested the functional characteristics of each subdivision in two ways: i) we measured position selectivity within each subdivision using multivariate pattern analysis on data from the object discrimination task, and ii) we computed the pattern of resting state correlations across the brain using each pulvinar subdivision as a seed. In preliminary data from four subjects, we found lateral, medial, and inferior clusters within the pulvinar that displayed distinct profiles of resting state activity. Within independent data, these clusters also showed differences in position selectivity, with the lateral cluster supporting the best decoding of object locations. Mirroring this pattern of position selectivity, the lateral pulvinar cluster was strongly correlated with early visual cortex in the resting state signal. These preliminary results point toward the presence of functionally distinct subregions within the human pulvinar and demonstrate an approach for parcellating the pulvinar based on a combination of resting state and task-related fMRI.

63.428 Spatial frequency tuning characteristics of primate superior colliculus neurons

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Superior colliculus (SC) receives various visual inputs including from retina, LGN, and V1. Each of these areas has different spatial frequency (SF) tuning characteristics: retinal output and LGN neurons are predominantly low-

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pass and tuned for low SF's, whereas V1 neurons can be band-pass. However, collicular SF tuning properties in primates are completely unknown. Here, we characterized these properties. We recorded activity from 50 neurons of one monkey fixating a white spot over a gray background. Inside a neuron's response field (RF), a high-contrast, vertical Gabor grating having one of five SF's (0.56, 1.11, 2.22, 4.44, 11.11 cpd) appeared. We measured peak neuronal activity 30-150 ms after stimulus onset and divided neurons based on their preferred retinotopic eccentricity. We characterized visual (V) and visual-motor (VM) SC neurons, and we excluded trials in which stimulus onset occurred <100 ms from microsaccades, to avoid peri-microsaccadic modulations in activity. All neurons (17 V; 33 VM) showed low-pass characteristics, but foveal neurons had slightly peaked tuning curves. Neurons with RF centers between 0.6 and 3 deg preferred SF's up to 4.44 cpd. Slightly more eccentric neurons (<8.5 deg) were most responsive for up to 1.11 cpd. The remaining neurons (<16 deg in our population) only preferred 0.56 cpd and sharply reduced their activity for all other SF's. V and VM neurons behaved similarly, but the visual response to preferred SF's was ~42% lower in VM than in V neurons. We also analyzed visual burst latency. Interestingly, this latency increased progressively with SF even for neurons that preferred higher than the lowest SF. Thus, SC shows clear SF tuning, but this tuning appears different from V1. Besides clarifying SC visual properties, this observation is interesting because it could potentially explain visual performance changes in V1-lesioned 'blindsight' patients, for whom the collicular visual pathway is presumably important.

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63.429 Spatiotemporal properties of macaque retinal ganglion cells: an harmonic analysis and relationships to psychophysical data

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Here we analyze the linearity of Magnocellular and Parvocellular Retinal Ganglion Cell (MC & PC RGCs) responses to complex waveforms (square-waves and ramps) and consider the responses in the context of psychophysical sensitivity. If linearity holds, then the responses to other waveforms should be predictable from the responses to sine-waves; Campbell & Robson (1968) tested this psychophysically. However, Campbell & Robson assumed that noise is similar across spatial frequency and did not consider temporal response properties. Here we test these assumptions with RGC responses. First we consider linearity; responses of RGCs to sine and complex waveforms were collected at 2Hz across a range of spatial frequencies and multiple contrast values. To predict the amplitude of complex waveform harmonic components, SF spectra for sine-wave responses were fit (DoG for MC and SoG for PC RGCs) and scaled to account for spatial frequency and the coefficients of the square-wave or ramp fourier expansion. Fits to fundamental harmonics were satisfactory, however, the amplitude of higher odd harmonics was better accounted for with additional scaling for the temporal response properties of RGCs. Such effects will happen with eye movements, and we then consider cell responses in the context of a Spatiotemporal surface as proposed by Kelly (1979) for psychophysical data. These findings suggest substantial linearity and spatiotemporal separability of RGC responses to complex waveforms. Secondly we consider variance; noise in RGC responses to sinusoidal modulation increases with temporal frequency (Sun et al., 2004). Here, we extend this analysis to higher harmonic square-wave response components. Noise increased in higher harmonic response components i.e., is not invariant. However, the increased response associated with higher temporal frequencies compensates for this. This has implications for the way cortical mechanisms process (summate) RGC responses to produce psychophysically observed effects.

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63.430 Activity in early visual areas reflects the trial-by-trial precision of perception

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The information received from our senses is typically consistent with a range of possible stimulus values, making any of our perceptual decisions uncertain. It is well known that this perceptual uncertainty affects behavior, but how does the brain represent knowledge of uncertainty? We used functional MRI in combination with pattern-based analyses to address this question. Participants viewed annular gratings of random orientation. Shortly after the presentation of the grating, observers reported its orientation. We used a novel pattern-based decoding approach to analyzing fMRI data, computing for each trial of BOLD activity the likelihood function of stimulus orientation. This approach differs from conventional decoding approaches in that the latter typically generates a single orientation estimate, whereas our method computes a full probability distribution over all possible orientations. We hypothesized that the width of the decoded probability distribution might reflect the degree of perceptual uncertainty. Accordingly, we compared the width of this distribution with behavioral variability, reasoning that more precise stimulus representations in visual cortex should be linked to less variable (more accurate) behavior. We found that perceptual uncertainty could reliably be decoded from fMRI activity patterns in the visual cortex. Specifically, the trial-to-trial fluctuations in the width of the likelihood function reliably predicted the variability in the observer's response. In contrast, we observed no link between the overall amplitude of the BOLD response and behavioral performance. These findings provide some of the first evidence that the trial-by-trial precision of perception can reliably be extracted from the human visual cortex.

63.431 Cholinergic enhancement increases information content of stimulus representations in human visual cortex

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Acetylcholine (ACh) plays an important role in cognitive processes such as attention and learning, by modulating neuronal responses in many cortical areas. Electrical stimulation of the basal forebrain (BF), the main source of cortical ACh, increases the reliability of neuronal responses in primary visual cortex of anesthetized rats and decreases redundancy, thereby increasing the information content of stimulus representations (Goard and Dan, 2009). To test the effects of ACh on the fidelity of representations of complex time-varying stimuli in the human brain, we administered the cholinesterase inhibitor donepezil in a double-blind, placebo-controlled cross-over design, while measuring fMRI responses to multiple repetitions of a movie segment containing a natural scene. Mutual information between fMRI responses and the stimulus was quantified by decoding the presented stimulus from multi-voxel activity in multiple visual field maps in early visual cortex (V1, V2 and V3). Donepezil administration improved decoding performance, suggesting that ACh enhances the information content of stimulus representations in visual cortex of awake behaving humans. On some presentations of the movie segment, subjects continuously performed a local contrast decrement detection task within either the left or right side of the movie, while maintaining central fixation. This detection task required sustained allocation of visual spatial attention to one hemifield, and this resulted in decreased mutual information between visual cortical activity and the movie stimulus in portions of early visual cortex representing the attended hemifield (e.g., in the right hemisphere, when target detection was performed in the left visual field). That is, decoding performance decreased when visual attention was allocated to the location, but not the features, of the movie stimulus. This decrease in information by spatial attention occurred in both placebo and donepezil sessions.

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63.432 Filling-in of an Induced Foveal Scotoma in Human Visual Cortex

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Introduction: 'Filling-in' occurs when an attribute such as brightness or motion is induced in a blank region of the visual field by the surrounding stimulus. Measuring the neural correlates of filling in with fMRI is complicated by spatio-temporal blurring and nonlinearities associated with the BOLD signal. Here we avoid these complexities by visualizing the effects of filling-in using a novel neural image method based on population receptive fields (pRF) 1. Methods: We estimated the pRFs that best predicted each voxel's time course to a multifocal (spatiotemporally random) stimulus in areas V1-V3 in three normally sighted individuals. We then measured fMRI responses to a drifting bar within a 16° aperture either with or without a central 2° blank 'scotoma'. For both stimuli, 'neural image' time-courses were generated by summing each voxel's Gaussian pRF in visual space scaled by its fMRI response at that time-point. To account for spatio-temporal blurring and nonlinearities in the BOLD signal, we compared these 'real neural images' to a 'model neural image' generated by convolving the stimulus time-course with each subject's estimated HDR and pRFs, with the inclusion of a model of BOLD spatio-temporal nonlinearities. Results: For the stimulus without a scotoma, model and real neural images are remarkably similar and resemble the drifting bar

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stimulus, delayed in time by BOLD hemodynamics. With the scotoma, the model neural image shows the expected drop in foveal response. In contrast, the scotoma had almost no effect on the real neural image. Differences between the model and real 'neural image' can be attributed to neural 'filling in'. Conclusion: We describe here a novel neural image method that estimates neural responses independently of the effects of spatiotemporal blurring and nonlinearities, and show that it can demonstrate the effects of neural filling in for a drifting bar stimulus in foveal V1-V3.

63.433 **Surround suppression in amblyopic central vision** Carey Y. L. Huh[1,2](careyhuh@gmail.com), Eunice Yang[1,2], Michael Silver[1,2], Dennis Levi[1,2]; [1]School of Optometry, University of California, Berkeley, [2]Helen Wills Neuroscience Institute, University of California, Berkeley

Amblyopia is typically characterized by reduced contrast sensitivity in the affected eye, particularly for high spatial frequencies that provide information about fine details in the visual scene. While this deficit suggests decreased gain of neural responses to high spatial frequencies, it is unclear whether lateral interactions among neurons are abnormal in amblyopia, and if so, whether the abnormality is specific to high spatial frequencies. To examine inhibitory lateral interactions, we measured surround suppression (SS) in adult amblyopes and age-matched normal observers. SS occurs when the detectability of a target is reduced by simultaneous presentation of a high-contrast stimulus surrounding the target. In normal observers, SS is much more pronounced in peripheral compared to central vision and may even be absent at the fovea. We found significant SS of a target grating in central vision of the amblyopic eye under conditions where little or no SS was found in either the non-amblyopic eye or in normal observers. For target gratings that are eight cycles wide, substantial SS was found in the amblyopic eye over a wide range of spatial frequencies (20 – 40% of the amblyopic eye's cutoff spatial frequency). In addition, SS was selective for surround gratings having the same orientation as the target, and significant SS was observed for centrally- and eccentrically-fixating amblyopes. Furthermore, we found that SS in amblyopic central vision was stronger for small target sizes, similar to normal peripheral vision. We are currently investigating the relationship between spatial frequency and SS and whether SS magnitude is proportional to the contrast sensitivity deficit of individual amblyopes. Our results demonstrate that amblyopic central vision displays substantial surround suppression that is absent or minimal at the fovea of normal observers. This finding supports the notion that amblyopia is characterized by abnormal interactions between neurons encoding neighboring visual field loci.

63.434 **Two mechanisms subserve the oblique effect** Kyriaki Mikellidou[1](kyriaki.mikellidou@for.unipi.it), Peter Thompson[2], David Burr[3]; [1]Department of Translational Research On New Technologies in Medicine and Surgery, University of Pisa, [2]Department of Psychology, University of York, [3]Department of Neuroscience, University of Florence

Introduction: The origins of the well-known oblique effect (poor discrimination for oblique orientations) are still unclear. Some studies point to asymmetries in orientation tuning in primary visual cortex (Furmanski & Engel, 2000), while others suggest it is related to gravitational vertical (Day & Wade, 1969). We disentangled these two alternatives by measuring precision of orientation discrimination at different angles of head-tilt, both while seated normally and lying horizontally to eliminate gravity. Methods: Participants indicated which of two sequentially presented gratings appeared more clockwise, for 12 different base orientations ranging from 0° (vertical) to ±90°. Psychometric functions were fitted with gaussian error functions, whose standard deviation gave an estimate of threshold. In different sessions, subjects either sat upright on a chair or lay horizontally on their back. In the upright condition the task was performed at three different head tilts (0°, 15°, 30°). In the horizontal condition, both the head and the body were either orientated at 0° or 30° or dissociated with the head positioned at 30° and the body at 0°. Results: In the upright position, thresholds were always lower at gravitational 0° or 90°, irrespective of head tilt, with no significant differences between the three head positions. On the other hand, in the absence of gravity, orientation discrimination depended primarily on retinal coordinates, varying with the tilt of the head. Conclusion: Our results reveal two distinct mechanisms causing the oblique effect: the strongest is gravity-based, independent of head position. However, when gravity is unavailable, a retinotopic oblique-effect emerged, probably reflecting asymmetries in orientation tuned mechanisms in early visual cortex. The results reconcile previous apparently conflicting evidence, and are in accordance with recent evidence on variable primate vestibular signals of different brain areas to changes in eye, head and body positions (Chen et al., 2013).

63.435 **Does perceptual learning transfer between 1st and 2nd order mechanisms that mediate fine orientation discriminations?** Lynn Olzak[1](olzakla@miamioh.edu), Mingliang Gong[1]; [1]Department of Psychology, Miami University of Ohio

Perceptual learning generally transfers between contrast-defined motion and luminance-defined motion, but not vice-versa (Mather & West, 1993; Lu & Sperling, 1995; Scott-Samuel & Georgeson, 1999). Vaina & Chubb (2012), however, reported no transfer either way, suggesting entirely separate 1st - and 2nd-order motion mechanisms. Here, we report the results of perceptual learning transfer between the 1st and 2nd order mechanisms mediating fine, static orientation discriminations. Ten observers participated in the study. Four had participated in several experiments previously, and were highly practiced making orientation judgments with 4 cpd luminance modulated (LM) gratings (contrast = 0.1). We then trained them with contrast-modulated, binary noise gratings (CM), also 4 cpd. We initially tested them at the same orientation difference that yielded a d' of 1.5 with LM gratings (approximately ±0.5 deg), also at a modulation depth of 0.1. No observer could perform the task above chance. We had to revert to ± 45 deg and shape responses over a period of months. Thresholds were about 10 times higher than found with LM gratings. Another four observers were new to the lab, and were initially trained with the CM gratings. Again, we found we had to start at ±45 deg and shape down to a final difference threshold of about ±5.0 deg. There was no difference in the trajectories of the two groups, suggesting that there was no transfer of perceptual learning from the 1st order to the 2nd order mechanisms. We are in the process of testing for transfer of perceptual learning from the CM to the LM mechanisms. Preliminary evidence suggests that there may be some transfer, but it is not yet clear whether this will be significant. The remaining two observers, also new to the lab, were trained on LM gratings, to provide the control learning trajectory against which the latter transfer group will be compared.

63.436 **Limiting Factors in Form and Motion Perception: Shared locally, Differentiated Globally** Mahesh Raj Joshi[1](mahesh.joshi@gcu.ac.uk), Anita J Simmers[1], Seong Taek Jeon[1]; [1]Vision Research Group, Department of Vision Sciences, Glasgow Caledonian University

The visual system is functionally differentiated into dorsal (motion) and ventral (form) pathways, owing to the limitations in previously employed stimuli analogous comparison of the outputs from these two streams has proven difficult. In the current study, we adapted the equivalent noise paradigm to (1) disentangle the effect of local and global limits on motion and form perception and (2) compare how those constraints manifest in the two pathways. Six visually normal observers estimated the mean direction or orientation (clockwise or counter-clockwise of vertical) of a field of moving dots (Random Dot Kinematogram; RDK), static dipoles (Glass Pattern; Glass), or dynamic dipoles (dynamic Glass pattern; dGlass) whose direction/orientations were drawn from normal distributions with a range of direction/orientation variances. Thresholds (τ) obtained after five sessions for each stimulus condition showed a consistent pattern across observers and external variance levels, where τGlass>τdGlass>τRDK. Overall, the average threshold ratios between the tasks were constant (1.13, 0.72, and 0.42 log units across external variance levels for τGlass /τRDK, τdGlass/τRDK, and τGlass/τdGlass, respectively), suggesting a parallel vertical shift in performance. This pattern of result was confirmed by the mixed ANOVA where we found significant effect of the external variance ($F_{6.03, 524.37}$= 185.33, p <.001) and the stimulus type ($F_{2, 87}$ = 33.50, p <.001), but no interaction between them ($F_{12.05, 524.37}$= 1.05, p > .1). Nested model comparisons where the thresholds were related to the external variances, internal noise, and the sampling efficiency revealed that change in performance between the tasks can be best described by the sole change in sampling efficiency with the internal noise remained invariable across tasks. Our findings provide a concurrent framework in which to consider global motion and form integration in human perception. This may prove valuable in diagnosing functional visual deficits in a range of developmental/cognitive disorders.

63.437 **Pain Tolerance Predicts Spatial But Not Temporal Vision Thresholds in Human Adults** Michele E. Mercer[1](michelem@mun.ca), Geoff L. Smith [1], Paul A.S. Sheppard[1]; [1]Department of Psychology, Faculty of Science, Memorial University

Purpose: Previously (VSS 2013), we reported a surprising relationship between two seemingly independent sensory modalities, namely human vision and pain. Specifically, adults' ability to tolerate heat and pressure pain was negatively correlated with performance on tests of spatial contrast sensitivity (CS). However, this effect was found only within a limited sample of adults who were tested repeatedly in order to reduce intra-subject variability. To better assess the robustness of this effect, and to explore

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the possible neural mechanisms that may underlie sensory interactions, we evaluated the relationship between pain and vision (both spatial and temporal) in a much larger group of young adults. Methods: Measures of spatial contrast sensitivity (FACT, Vector Vision, Rabin) and temporal photopic and mesopic flicker fusion thresholds were assessed binocularly in 105 healthy young adults (M = 23 yr; 62 females, 43 males). Within the same session, threshold and tolerance to both contact heat (arm) and pressure pain (pinky finger) were also assessed. Results: Correlational analyses revealed a strong relationship between all measures of CS and heat pain tolerance (all r > - 0.65), although results for pressure pain were more modest. Specifically, those who showed lower tolerance for heat pain (were more sensitive to pain) also showed higher levels of contrast sensitivity. Conversely, measures of critical flicker fusion thresholds appeared unrelated to any of the pain measures. Conclusions: Human adults show a relationship between heat pain sensitivity and spatial vision, but not between pain and the present measures of temporal vision. Given that dopamine is heavily involved in the processing of both pain and spatial information in the CNS, this raises the interesting possibility that the observed co-variation in sensitivity may be explained by dopaminergic involvement.

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63.438 **Retinotopic visual mapping of brain oxygenation and neuronal activity using simultaneous fast and slow near-infrared optical brain imaging in humans.** Kyle E. Mathewson[1](kylemath@gmail.com), Kathy A. Low[1], Nils Schneider-Garces[1,2], Antonio Chiarelli[1], Chin Hong Tan[1,2], Tania Kong[1,2], Courtney R. Burton[1], Mark A. Fletcher[1,3], Benjamin Zimmerman[1,3], Brad P. Sutton[1,4], Edward L. Maclin[1], Monica Fabiani[1,2], Gabriele Gratton[1,2]; [1]Beckman Institute for Advanced Science and Technology, University of Illinois, [2]Department of Psychology, University of Illinois, [3]Neuroscience Program, University of Illinois, [4]Department of Bioengineering, University of Illinois

High-precision retinotopic mapping of the visual field normally uses BOLD signal. Given the divergence between neuronal and hemodynamic responses with aging, however, a more direct measure of neuronal activity is needed to make accurate maps of retinotopic organization. We employed tri-modal neuroimaging of 18-78 year-old subjects using BOLD-fMRI, along with a separate session of simultaneously acquired near-infrared spectroscopy (NIRS) and fast-optical imaging (FOI), to test the correspondence among retinotopic maps derived from these techniques. Identical stimuli presented in the MRI and optical sessions consisted of checkerboard gratings expanding or revolving every 48 seconds (1/48 Hz), flickering at 5 Hz. We passed modulated near-infrared light through visual cortex using 8 pairs of 690- and 830-nm laser diodes and 16 photomultiplier tube detectors. The source and detector locations were co-registered with the scalp from each individual's MPRAGE image, and the light's path through the tissue was modeled in the subject's original brain space. The activity in each voxel was computed as a weighted sum of the amplitude (NIRS-HbO2) and phase (FOI) of light passing though each channel. We segmented and parcellated each subject's MPRAGE using FreeSurfer, and flattened the occipital surface cut along the calcarine fissure, mapping both the fMRI and optical retinotopy results in this space. For both BOLD and HbO2, we extracted the phase and amplitude of the 1/48-Hz signal. For FOI we used short moving-window wavelets to compute the time course of 5-Hz flicker power in each voxel, from which the phase and amplitude of the 1/48-Hz grating were computed. Results show a strong correspondence between optical and BOLD retinotopic maps, onto which we can map event-related optical signals (EROS) evoked by stimuli of varying eccentricities. These results reveal the potential for retinotopic mapping in both space and time afforded by fast optical imaging of the human brain.

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Spatial vision: Texture

Wednesday, May 21, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

63.439 **Investigating the shape of the contrast sensitivity function using white, bandpass, and contrast jitter noise** Alex S. Baldwin[1](alexsbaldwin@googlemail.com), Robert F. Hess[1]; [1]McGill Vision Research, Department of Ophthalmology, McGill University

An equivalent noise experiment was conducted to investigate the effect of spatial frequency on contrast sensitivity. Under the linear amplifier model, performance can be accounted for by the efficiency of the mechanism responsible for detecting the target (relative to an ideal observer) and the variance of its internal noise. Previous studies have found conflicting results as to whether efficiency varies with spatial frequency, or if the threshold differences are due entirely to changes in internal noise variance. These experiments have frequently used broadband noise, which has the disadvantage of also activating non-target mechanisms. This leads to additional threshold elevation due to cross-channel masking (through the contrast gain pool), resulting in a confound in experiments where the relationship between the noise and target spectra is not constant. Baker & Meese [2012, Journal of Vision, 12(10):20, 1-12] proposed a novel noise masking method, where the noise is simply a contrast-jittered version of the target. This injects the noise directly into the target mechanism, minimising contrast gain pool effects. In this study, observers detected a horizontal log-Gabor target at five spatial frequencies (0.25 – 4 c/deg) in three types of noise: broadband (2D white), tuned to the target channel (2D noise filtered to have the same power spectrum as the target), and tuned to the target mechanism (contrast jitter). For each noise type, the fitted internal noise variance parameter increased with spatial frequency. In 2D white noise the fitted efficiency parameter increased with spatial frequency from 17% to 55%. In 2D filtered noise and contrast jitter noise efficiency was flat across spatial frequency at 59% and 88% respectively. By tuning our noise to the target mechanism at each spatial frequency we show that efficiency is constant, and that the decline of the contrast sensitivity function arises solely from increasing internal noise.

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63.440 **Perceptual biases and comparison biases in noisy 2D orientation displays** Elizabeth Cifuentes[1](ecifuen1@swarthmore.edu), Michael Fishman[1], Frank Durgin[1]; [1]Department of Psychology, Swarthmore College

Two different biases have been reported for 2D orientation. For estimation and bisection tasks, deviations from horizontal tend to be exaggerated (Durgin & Li, 2011). For noisy orientation comparison tasks, symmetrical biases toward both cardinal orientations have been reported (Girschick et al., 2011; Tomassini et al., 2010). One source of additional bias in a comparison task might be memory encoding. To test for memory-dependent bias effects we developed a forced choice staircase procedure in which observers (N=52) judged, for each presented texture of oriented Gabor patches, whether the mean orientation was clockwise or counterclockwise from a reference line present on the screen. Three different reference orientations were used (15°, 45° and 75°); the standard deviations of orientation for the test textures were 0°, 9°, or 18°. For half the participants, measurements relative to the three reference orientations were blocked so that textures were being compared to the same orientation within each block (low memory load). For the remaining participants the different reference orientations were interleaved in random order so that line orientation had to also be encoded on each trial. If noise-dependent orientation biases are perceptual, these two experimental conditions should produce the same patterns of increased bias toward the cardinal orientations as orientation noise increases. In fact, a reliable Blocking x Noise interaction (p <.05) indicated that cardinal bias was only reliably present when the different references were interleaved (p <.05). When blocked so that a memory representation of the reference stimulus could be used from trial to trial, no reliable cardinal biases were found (p > .10). A follow-up study in which observers lay rotated 45° counterclockwise relative to the display supported the interpretation that the cardinal bias in the interleaved condition was a memory bias relative to the range of reference stimuli presented rather than a cortical cardinal orientation bias.

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63.441 **Mapping number to space engages adaptive encoding mechanisms** David Burr[1,2](dave@in.cnr.it), Guido Marco Cicchini[2], Givanni Anobile[1]; [1]Department of Neuroscience, University of Florence, [2]CNR Institute of Neuroscience, Pisa

The mapping of number onto space is fundamental to measurement and mathematics. However, number mapping of young children, unschooled adults and adults under attentional load show strong compressive non-linearities, thought to reflect intrinsic logarithmic encoding mechanisms, which are "linearized" by education. Here we advance and test an alternative explanation: that the non-linearity results from adaptive Bayesian mechanisms (akin to a Kalman filter), which take into account the statistics of recent stimuli. This theory predicts that the response to the current trial should correlate positively with the magnitude of the previous trial: whereas a static logarithmic non-linearity predicts trial-wise independence. Consistent with predictions, we found strong and highly significant correlations between numberline mapping of the current trial and the magnitude of previous trials, in both adults and school children. The dependency is sufficient to account for the shape of the numberline (using a simple, one-parameter model), without recourse to static non-linearities such as logarithmic encoding. Simulations show that this dynamic strategy is efficient, resulting in a reduction of overall reproduction error, and may well reflect a general strategy to cope adaptively with environmental statistics.

Acknowledgement: ERC

63.442 **Invariant texture recognition depends on high-order statistics**

Catherine Conlin[1](cat.conlin@gmail.com), Benjamin Balas[1]; [1]Psychology Dept., North Dakota State University

Texture synthesis models based on joint statistics of wavelet coefficients across scale, orientation, and position have become a popular tool for studying the representations that support texture processing in the human visual system. In particular, the summary statistics implemented in the Portilla-Simoncelli model account for observer performance in crowding, search tasks, and the response properties of V2 neurons. Presently, we chose to investigate whether or not this set of summary statistics was also sufficient to support performance in a texture discrimination task that required invariance to illumination. We selected 14 pairs of visually-matched textures from the Amsterdam Library of Textures, including a diverse range of material properties. Each texture was depicted under two illumination conditions: diffuse overhead lighting and strong side lighting. We generated a synthetic image from each original texture image using the Portilla-Simoncelli model. Using these images, we asked observers (N=13) to complete four match-to-sample tasks. Each task briefly presented (250ms) a sample texture to be matched to one of two test images presented after a 500ms ISI- one test image depicted the same texture as the sample, the other a visually-matched distractor. In the Illumination-change condition, the target texture and the sample were differently illuminated; In the No-change condition, lighting was the same. Observers completed both conditions using real and synthetic textures in separate blocks. We observed significant main effects of real/synthetic appearance ($p<0.001$) and illumination condition on accuracy ($p<0.001$), qualified by an interaction between these factors ($p<0.001$), such that performance in the No-change condition was slightly worse for synthetic textures (~5% cost), but that this difference was much larger in the Illumination-change condition (~20% cost). We conclude that invariant texture recognition relies on statistics not included in the P-S model and natural texture appearance overall leads to better discrimination performance.

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63.443 **Perceptual requirements and consequences of lateral inhibition**

Joshua Solomon[1](J.A.Solomon@city.ac.uk), James Kraft[2], Charles Chubb[3]; [1]Centre for Applied Vision Research, City University London, [3]Department of Cognitive Sciences, University of California at Irvine

Lateral inhibition is thought to underlie most forms of contextually induced repulsion. Examples include simultaneous contrast and the tilt illusion. It may seem strange that evolution has favoured a sensory apparatus that distorts the relationships between its stimuli, but it is possible that such distortion is accompanied by an increase in sensitivity. If this hypothesis is correct, then observers should be relatively insensitive to stimuli defined by feature dimensions in which repulsion does not occur. We searched for a dimension like this by systematically manipulating texture statistics. Luminance (a first-order statistic) obviously does not qualify, nor does contrast (a second-order statistic), but contrast-contrast (a fourth-order statistic) might. Orientation does not qualify, but orientation bandwidth might. Testing for repulsion between high-order texture values is difficult because the boundary between textures having different values is often indistinct. Might repulsion be predicted from boundary visibility? Not very well. Our re-analysis of Bosten and Mollon's (2010) data suggests a moderate correlation ($r = 0.60$) across 9 feature dimensions for population median indices of repulsion and sensitivity. On the other hand, our measurements, which confirm large repulsions across contrast-defined and orientation-defined texture boundaries that were twice their detection thresholds, revealed only inconsistent repulsion across equally visible boundaries defined by orientation-bandwidth. Using a d′ of 1.4 to define the just-noticeable difference, there are only 4 or 5 noticeably different orientation bandwidths. We considered the possibility that there might be a correlation between this JND gamut and various indices of repulsion, but back-of-the-envelope calculations did not support this notion. Two further predicted consequences of lateral inhibition similarly failed to manifest in our laboratory: 1) a concomitant decrease of repulsion and discriminability with the distance between spatially separated textures (also absent from Mollon & Danilova, 2003) and 2) resistance from low-frequency masking (also absent from Westrick et al, 2013).

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63.444 **Order-disorder transition in visual perception**

Mikhail Katkov[1](mikhail.katkov@gmail.com), Hila Harris[1], Dov Sagi[1]; [1]Neurobiology department, Weizmann Institute of Science

Whereas receptive fields of the primary visual cortex have been extensively characterized, the integration mechanisms constructing a global percept from these local computations are largely unknown. Additionally, it has been suggested that the visual system is tuned to the statistics of the external environment. We tested what statistical properties of visual stimuli may underlie integration processes. Specifically, we examined the sensitivity of human vision to order-disorder transition in visual textures. We employed a set of textures generated from different homogeneous Markov Random Fields (MRF). Changing a one-dimensional parameter (analogous to the thermodynamic temperature in Boltzmann distribution), the generated textures vary from random (independent identically distributed amplitudes, IID) to ordered. An order parameter, used in statistical physics to identify order-disorder transition was estimated for each MRF. We measured psychometric function (performance vs. the MRF parameter) in a 4AFC task. In each display one texture was controlled by the MRF parameter while the other three were random textures. Observers (n=7) were requested to report in which quadrant of display the most ordered texture appeared. Human performance followed the order parameter curve for MRF where many visually different images corresponded to the same ordered state. Notably, for MRFs with a single image corresponding to an order state (prototype image), such as vertical gratings or checkerboards, a lower level of order was required to identify the texture as ordered. All observers were substantially outperformed by an ideal observer based on bootstrapped likelihood ratios between sufficient statistics. Our results suggest that integration mechanisms in the visual system effectively compute an order parameter representing qualitative changes in images, such as order-disorder. A visually prototyped image enabled enhanced order sensitivity. Moreover, the human visual system lacks the flexibility required to form an efficient representation (sufficient statistics) for the given task.

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63.445 **Spatial integration of orientation-defined texture**

Gunnar Schmidtmann[1](info@gunnarschmidtmann.com), Ben Jennings[1], Jason Bell[2], Frederick Kingdom[1]; [1]McGill University, Department of Ophthalmology, Vision Research, [2]The University of Western Australia, School of Psychology

Previous studies have reported linear summation for Glass patterns from measures of detection thresholds as a function of signal area, and have proposed specialized concentric orientation texture detectors (Wilkinson et al., 1997; cf. Dakin & Bex, 2002). Motivated by these findings and recent results in curvature discrimination showing strong summation of curvature information for circular segments up to 180˚ (semi-circle) (Schmidtmann et al., 2013), we investigated spatial integration for a variety of different orientation-defined textures (circular, radial, spiral, translational) composed of 150 Gabor patches. In a 2AFC, subjects had to detect the texture in a single randomly positioned pie-wedge sector of varying angular extent ranging from 36˚ - 360˚. The signal to noise ratio in that sector was varied, whereas the remaining array contained randomly oriented elements (noise only). Results show that, contrary to previous studies, detection thresholds for all texture types decrease with angular extent following a power-law function with an exponent around -0.5. To investigate the role of spatial uncertainty we fixed the angular position of the sector containing signal elements. This improved performance disproportionately for small sectors, resulting in even weaker summation across angular extent and can therefore not explain any lack of summation. Next we analyzed the correlation between correct responses and clustering of signal elements. Results show that observers are more likely to make correct responses if signal elements are clustered (high density). To summarize, we found that, a) the detection of orientation-defined texture is independent of texture type; b) summation across area was weaker than reported previously and c) summation strength is further reduced by adding spatial certainty. We suggest that detecting local clusters of signal elements might limit the detection of global form in these textures.

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63.446 A unified framework and normative dataset for second-order sensitivity using the quick Contrast Sensitivity Function (qCSF) Alexandre Reynaud[1](alexandre.reynaud@mcgill.ca), Yong Tang[2], Yifeng Zhou[2,3], Robert Hess[1]; [1]McGill Vision Research, Dept. Ophthalmology, McGill University, Montreal PQ, Canada., [2]CAS Key Laboratory of Brain Function and Diseases and School of Life Sciences, University of Science and Technology of China, Hefei, People's Republic of China., [3]State Key Laboratory of Brain and Cognitive Science, Institute of Biophysics, Chinese Academy of Science, Beijing, People's Republic of China.

Introduction: While the contrast sensitivity approach has been successful in quantifying striate function, there is a need to develop comparable ways of evaluating extra-striate function in humans. Neurophysiologically, the extra-striate cortex differs from the striate cortex in a number of important ways. Second-order modulated stimuli are thought to be processed by the visual system in two serial stages; the carrier is processed by the localized, spatially bandpass neurons in V1 and in a second stage the rectified V1 output is integrated in extra-striate cortex. Here, our purpose is to establish normative data on the sensitivity of extra-striate human cortical function. Methods: We optimally designed second-order stimuli contrast-, orientation- or motion-modulated in order to reflect extra-striate function. We use a common novel methodology, the quick contrast sensitivity function (qCSF) method, recently developed for the rapid measurement of visual contrast sensitivity across a range of spatial frequencies relevant to striate function (Lesmes et al., 2010). This method is a Bayesian adaptive procedure that estimates multiple parameters of the sensitivity function and concurrently estimates thresholds across the full spatial-frequency range. It was originally built to determine the first-order contrast sensitivity function, but here we use it for determining both first and second-order functions. Results: We first show that the qCSF methodology can be well adapted to different kinds of first- and second-order measurements. We provide a normative dataset (102 eyes) for first- and second-order sensitivity and we show that the sensitivity to all these stimuli is equal in the two eyes. Conclusions: Our results confirm some strong differences between first- and second-order processing, in accordance with the classical filter-rectify-filter model. They suggest a unique contrast detection mechanism but different second-order ones.

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63.447 Contour integration affects perceived mean orientations of Gabors Oakyoon Cha[1](oakyoon@yonsei.ac.kr), Sang Chul Chong[1,2]; [1]Graduate Program in Cognitive Science, Yonsei University, [2]Department of Psychology, Yonsei University

When adjacent elements have similar orientation, a contour integration occurs (Field et al., 1992). Similarly, as the orientations of stimuli become similar the spatial integration of the orientation becomes easier (Dakin, 2001). In the current study, two experiments investigated the effects of contour integration on perceived mean orientations of Gabors. A set of Gabors, some of which induced vertical contours in specific orientations, was presented in an imaginary circle and points of subject equality (PSE) were measured. In Experiment 1, sixty Gabors of 7 stepwise mean orientations (ranging from 4.5° counter-clockwise to 4.5° clockwise with a step of 1.5°) were presented and participants were asked to report whether the mean orientation of the Gabors was counter-clockwise or clockwise. On 50% trials (contour condition), nine out of the 60 Gabors were aligned to induce a vertical contour with the orientation of -6°, 0°, or 6° from the vertical meridian. On the rest (non-contour condition), 9 Gabors were randomly placed and did not induce a vertical contour. We found that the orientation of the contour biased participants' PSEs into the same orientation, shifting perceived mean orientations of the Gabors to the opposite directions. In addition, using the psychometric functions of the non-contour condition, we predicted each participant's responses in the contour condition, suggesting that mean orientation judgments were made separately from the orientations of the 9 Gabors. Experiment 2 was designed to assess the extent to which mean orientation judgments were affected by 9 Gabors aligned but not inducing contours. Nine Gabors were aligned horizontally but these Gabors were vertically oriented. The pattern of PSE shifts was reversed compared to Experiment 1. The results in the two experiments suggest that Gabors inducing an integrated contour do not contribute to mean orientation judgments.

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63.448 The neural response to visual symmetry in wallpaper patterns Peter J. Kohler[1](pjkohler@stanford.edu), Alasdair D. F. Clarke[2], Joan Liu-Shuang[3], Yanxi Liu[4], Anthony M. Norcia[1]; [1]Department of Psychology, Stanford University, [2]Institute for Language, Cognition and Computation, The University of Edinburgh, [3]Institute of Research in Psychology, University of Louvain, [4]College of Engineering, Penn State University

Symmetry is a striking visual attribute that occurs in nature and has been used by artists since the Neolithic age. All two-dimensional periodic patterns can be mathematically associated with one of 17 wallpaper symmetry groups, each containing unique combinations of Euclidean plane isometries (translation, rotation, reflection and glide). Recent behavioral work has shown that pattern similarity judgments by human observers are to a large extent driven by this group structure (Clarke et al., Symmetry, 2011). How are these perceptual and mathematically defined similarities between wallpaper groups represented in human neural activity? We investigated this question with Visual Evoked Potentials. Our experimental design allowed us to clearly separate the configural response to the symmetry from the evoked response to local contrast change. We presented patterns associated with five different wallpaper groups that have different rotation isometries, but are otherwise equivalent (P1,P2,P3,P4,P6). Participants (n=9) performed a contrast-change detection task that was orthogonal to judging pattern similarities. They all elicited a configural response, but there were differences in the symmetry response dynamics and waveforms between the groups, with at least three qualitatively distinct types of neural responses. P3, a group that human observers found difficult to categorize (Clarke et al., Symmetry, 2011), had the weakest configural response of the five wallpaper groups tested, suggesting a correspondence between behavioral and neural data. We also found systematic group-level differences in the latency of the symmetry response, such that simpler groups with fewer rotation isometries (P1,P2) elicited an earlier response than groups with more rotation isometries (P4,P6). The weak response to P3 echoes low perceptual salience, while prolonged latency for patterns with more rotation isometries may reflect processing costs associated with wallpaper group complexity. Future work will explore and distinguish the ways in which both types of information are represented in the brain.

Acknowledgement: NSF-INSPIRE 1248076

63.449 Early visual ERP components are sensitive to natural texture appearance Benjamin Balas[1](benjamin.balas@ndsu.edu), Catherine Conlin[1]; [1]Psychology, North Dakota State University

The visual system is tuned to natural image statistics in a variety of ways. Disruptions of natural texture appearance are known to negatively impact performance in texture discrimination tasks, for example, such that contrast-negated textures, synthetic textures, and textures depicting abstract art are processed less efficiently than natural textures. In the current study, we chose to examine how early visual ERP responses (the P1 and the N1) were affected by violations of natural texture appearance. Specifically, we presented participants with texture images that depicted either natural textures or synthetic textures made from the original stimuli . Both stimulus types were additionally rendered either in positive or negative contrast. These appearance manipulations (negation and texture synthesis) preserve a range of low-level features, but also disrupt higher-order aspects of texture appearance. We recorded continuous EEG while 15 participants (8 female) completed a same/different task using the textures described above. On each trial (128 per condition), participants viewed two texture patches presented in sequence (500ms per image, 1000ms ISI) and indicated via a button press whether the two images were identical or not. "Different" trials were comprised of two non-overlapping texture patches drawn from the same larger image. Visual ERPs were time-locked to the onset of the first stimulus in each pair to avoid response-related activity. Analysis of the P1 revealed no effects of either contrast negation or synthetic texture appearance on component amplitude or latency. Both factors did influence the N1 response, however: We observed main effects of contrast polarity (p=0.038) and natural vs. synthetic appearance (p<0.001) on the mean amplitude of the N1, as well as a main effect of synthetic appearance on latency (p=0.004). We conclude that this sensitivity to the differences between natural and unnatural textures suggests early processing of higher-order statistical regularities.

Acknowledgement: P20 GM103505

Wednesday AM

63.450 **Stimulus selectivity of broadband field potentials, but not gamma oscillations, matches population responses as measured by BOLD fMRI in human visual cortex** Dora Hermes[1](dhermes@stanford.edu), Kendrick Kay[2], Jonathan Winawer[3]; [1]Psychology Department, Stanford University, Stanford, [2]Psychology Department, Washington University in St. Louis, St. Louis, [3]Psychology Department, NYU, New York

Purpose: A number of neuroimaging tools are used to measure signals in the human visual system, including fMRI, MEG, EEG, and ECoG. Each measurement modality likely emphasizes different components of the neural circuitry. A better understanding of visual cortical function will require linking measurements across modalities. Here we studied visual signals with electrocorticography (ECoG) and compared previously collected fMRI responses to two different aspects of the neurophysiological response: narrow-bandwidth oscillation in the lower frequencies (centered between 25 and 70 Hz) and a broadband high-frequency signal (spanning at least 80–175 Hz). Methods: ECoG signals in visual cortex (V1-V4) were measured in response to a wide range of carefully designed stimuli (86 stimuli, 15 repetitions, 500-ms duration, random order). These stimuli varied systematically along dimensions such as spatial location, contrast, orientation, spatial frequency, and second-order contrast. Power spectra of the ECoG responses were computed and separated into broadband (80-175 Hz) and gamma responses (25-50Hz). Results: Broadband and gamma responses in V1/V2 exhibited strikingly different behaviors. Gamma responses were substantially stronger for stimuli with narrow orientation and spatial frequency content (i.e. sinusoidal gratings) compared to other stimuli, whereas broadband responses were substantially stronger for stimuli that contained broad orientation and spatial frequency content. The selectivity exhibited by the broadband responses, but not the gamma responses, better matched the selectivity exhibited by fMRI responses obtained from healthy control subjects. Conclusion: Our results show that the strongest gamma responses were elicited by high-contrast sinusoidal gratings; this was not true of the broadband response. We speculate that gamma oscillations reflect a resonant state elicited only by particular patterns of neuronal activity within a local region of cortex. The fMRI BOLD signal correlates better with the broadband response than with gamma oscillations, and likely reflects the overall neural response level within a cortical region.

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Face perception: Disorders, individual differences

Wednesday, May 21, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

63.451 **A proposal for developmental prosopagnosia 'sub-types' based on differential face perception and face memory performance** Sarah Cohan[1](sarahc@wjh.harvard.edu), Joseph DeGutis[1, 2]; [1]Vision Sciences Laboratory, Department of Psychology, Harvard University, [2]Geriatric Research Education and Clinical Center (GRECC), Boston Division VA Healthcare System, Jamaica Plain, MA, United States

Developmental prosopagnosia (DP) has shown to be a heterogeneous disorder (e.g., presence/absence of face detection deficits, presence/absence of a face-selective N170). Though there have been suggestions of possible DP sub-types (e.g., those with face-specific deficits vs. general object processing deficits), because of the relatively low sample sizes of most DP studies (N<15) these proposals have not been tested empirically. In the current study, we administered a battery of six perceptual and memory tests to 44 individuals who presented with clinical interview responses characteristic of developmental prosopagnosia (e.g., difficulty following characters on television and recognizing familiar people out of context). To characterize possible DP sub-types, we performed a hierarchical cluster analysis, using Ward's method to minimize total within-cluster variance. This produced three distinct clusters: the first included 13 participants with subjective face recognition complaints but with relatively minor face memory (z-score=-1.43) and face perception deficits (z-score average=-.96) and no significant holistic face processing deficits. The second (N=17) and third (N=14) clusters both had more severe face memory deficits (z-scores of -2.27 and -2.38, respectively) and demonstrated significant holistic face processing deficits. Interestingly, the third cluster also showed more severe deficits in face perception tasks (z-score average=-2.44) compared to the second cluster (z-score average=-1.5). Finally, none of the clusters differed in object perception, suggesting that this ability does not differentiate between DP sub-types. These results suggest that one sub-group of individuals with subjective face recognition difficulty do not show significant impairment on objective tests, questioning whether they should be considered prosopagnosic. Furthermore, our results suggest that individuals with more severe face recognition impairments can be divided into those with more and less severe face perceptual abilities. Together, this suggests that developmental prosopagnosia should not be considered a unitary category, and that dissociable mechanisms may cause very similar face recognition complaints.

Acknowledgement: National Institutes of Health 5R01EY013602-07, Ken Nakayama

63.452 **A dissociation between face perception and face memory in adults, but not children, with developmental prosopagnosia** Kirsten Dalrymple[1](kad@umn.edu), Brad Duchaine[2]; [1]Institute of Child Development, University of Minnesota, [2]Department of Psychological and Brain Sciences, Dartmouth College

Prosopagnosia is defined by severely impaired face recognition. Cognitive models of face recognition propose that it is accomplished through a series of discrete stages of processing. For example, Bruce and Young's (1986) influential model hypothesizes a separation between structural encoding of a face and face recognition units, which interact to encode new faces, or to retrieve memories of previously viewed faces. This division suggests that impaired face recognition can result from failures of face perception, face memory, or both. Evidence from individuals with acquired prosopagnosia supports the idea that face perception and face memory are dissociable, with perceptual deficits resulting from occipito-temporal lesions, and memory deficits resulting from more anterior lesions (Barton, 2003; Barton, 2008; Damasio et al., 1990). Developmentally, the early maturation of face perception and relatively protracted development of face memory in typically developing children points to the same dissociation (Weigelt et al., 2013). Despite the fundamental nature of this distinction, this potential dissociation has received little attention in the context of developmental prosopagnosia (DP) (Bowles et al., 2009; Stollhoff et al., 2011). To address this issue, we tested the face perception and face memory of children and adults with DP. We found that all children were impaired with face perception and face memory. In contrast, half of the adults scored normally for face perception. Thus results from adults indicate that face perception and face memory are indeed dissociable, while the results from children provide no evidence for this division. Given these findings we consider the possibility that DP is qualitatively different in childhood versus adulthood. We also consider alternative explanations, such as individual differences in perceptual strategies, but ultimately suggest that this topic warrants further investigation.

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63.453 **Do face and word recognition deficits dissociate? A study of four acquired prosopagnosics** Brad Duchaine[1](bradley.c.duchaine@dartmouth.edu), Tirta Susilo[1], Victoria Wright[2], Jeremy Tree[3]; [1]Psychological and Brain Sciences, Dartmouth College, [2]Seicoleg, Aberystwyth University, [3]Department of Psychology, Swansea University

Humans have extensive experience with both faces and words, and it has recently been proposed that face and word recognition rely on common mechanisms. This view predicts that acquired prosopagnosics will show word recognition deficits, though possibly to a lesser extent (Behrmann & Plaut, 2013 TICS). While normal word recognition in prosopagnosia has been reported before, it has not been examined rigorously with multiple tasks that incorporate response time. Here we investigated whether face and word recognition deficits co-mingle in four acquired prosopagnosics. Three prosopagnosics had lesions limited to the right hemisphere while one had bilateral lesions with more pronounced lesions in the right hemisphere. All reported problems with face recognition in daily life, but believed that their word recognition ability was normal. All showed severe face recognition impairments on standard laboratory tests. The prosopagnosics completed seven word recognition tasks: two lexical decision tasks and five reading aloud tasks, totaling more than 1,200 test items. All of them performed in the normal range across all tasks, and they were just as fast in responding as the controls. Our findings demonstrate that word recognition ability can be spared in acquired prosopagnosia and suggest that face recognition relies, at least in part, on mechanisms different than those used for word recognition.

Acknowledgement: Hitchcock Foundation

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63.454 **Facial motion does not help face recognition in congenital prosopagnosics** Janina Esins[1](Janina.Esins@tuebingen.mpg.de), Isabelle Bülthoff[1,2], Johannes Schultz[3]; [1]Max Planck Institute for biological Cybernetics, Tübingen, Germany, [2]Department of Brain and Cognitive Engineering, Korea University, Seoul, Korea, [3]Department of Psychology, Durham University, Durham, UK

Humans rely strongly on the shape of other people's faces to recognize them. However, faces also change appearance between encounters, for example when people put on glasses or change their hair-do. This can affect face recognition in certain situations, e.g. when recognizing faces that we do not know very well or for congenital prosopagnosics. However, additional cues can be used to recognize faces: faces move as we speak, smile, or shift gaze, and this dynamic information can help to recognize other faces (Hill & Johnston, 2001). Here we tested if and to what extent such dynamic information can help congenital prosopagnosics to improve their face recognition. We tested 15 congenital prosopagnosics and 15 age- and gender matched controls with a test created by Raboy et al. (2010). Participants learned 18 target identities and then performed an old-new-judgment on the learned faces and 18 distractor faces. During the test phase, half the target faces exhibited everyday changes (e.g. modified hairdo, glasses added, etc.) while the other targets did not change. Crucially, half the faces were presented as short film sequences (dynamic stimuli) while the other half were presented as five random frames (static stimuli) during learning and test. Controls and prosopagnosics recognized identical better than changed targets. While controls recognized faces better in the dynamic than in the static condition, prosopagnosics' performance was not better for dynamic compared to static stimuli. This difference between groups was significant. The absence of a dynamic advantage in prosopagnosics suggests that dysfunctions in congenital prosopagnosia might not only be restricted to ventral face-processing regions, but might also involve lateral temporal regions where facial motion is known to be processed (e.g. Haxby et al., 2000).

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63.455 **A possible marker of configural processing at the N170: Converging evidence from typical participants and a case of prosopagnosia** Natalie Mestry[1](Natalie.Mestry@soton.ac.uk), Tamaryn Menneer[1], Michael J. Wenger[2], Rosaleen McCarthy[1,3], Nick Donnelly[1]; [1]Psychology, University of Southampton, UK, [2]Psychology, University of Oklahoma, OK, USA, [3]Wessex Neurological Centre, Southampton, UK

Both orientation and Thatcherisation are thought to influence configural processing in faces (Boutsen, Humphreys, Praamastra & Warbrick, 2006). We explored the effect of orientation and level of Thatcherisation (typical face, eyes Thatcherised, mouth Thatcherised, or both features Thatcherised) on early ERP components. Participants showed evidence of inversion effects leading to increased amplitude for inverted faces at the N170 and reduced amplitude to inverted faces at the P2. However, the effect of Thatcherisation was only evident in the right hemisphere N170 where there was a reduction in N170 amplitude with level of Thatcherisation. These data suggest two distinct processes (consistent with Towler, Gosling, Duchaine, & Eimer, 2012). In a follow-up study using the same task we tested PHD, an individual with acquired prosopagnosia known to be unable to perceive the Thatcher illusion (Mestry, Donnelly, Menneer & McCarthy, 2012). We did so to explore whether the markers of orientation and Thatcherisation would survive in the ERP in the absence of sensitivity to the Thatcher illusion. PHD did show a significant effect of inversion at both the N170 and P2. However, PHD produced no effect of Thatcherisation at the N170, in contrast to the effect found with typical participants. The results suggest that the effect of Thatcherisation manifest in the right hemisphere N170 underpins the perception of the Thatcher illusion. As the effects of orientation at the N170 and P2 are also found in an individual who does not perceive the illusion, then they cannot reflect the type of configural processing affected by the Thatcher illusion (Donnelly, Cornes and Menner, 2012). In conclusion, the novel N170 Thatcherisation effect is a marker of a kind of configural processing present in typical face processing that is affected by Thatcherisation (Mestry, Menneer, Wenger, & Donnelly, 2012).

Acknowledgement: ESRC

63.456 **Caricaturing improves face recognition in simulated prosthetic vision.** Elinor McKone[1,2](elinor.mckone@anu.edu.au), Jessica L. Irons[1,2], Tamara Gradden[1], Xuming He[3,4,5], Nick Barnes[3,4,5]; [1]Research School of Psychology, Australian National University, [2]ARC Centre for Cognition and Its Disorders, Australian National University, [3]National Information and Communication Technology Australia (NICTA), [4]College of Engineering and Computer Science, Australian National University, [5]Bionic Vision Australia

Recent medical advances have allowed the development of "bionic eyes" (e.g., implanted in retina or V1). This prosthetic vision provides only a low-resolution view of the world, specifically a spatially separated array of "phosphenes" of light. While sufficient for some basic visual tasks such as navigating around large objects, recognition of individual faces is poor. The broad aim of the present work was to explore the hypothesis that image manipulations targeted at improving mid- and/or high-level processing of face identity can improve face recognition in the bionic eye. The manipulation we tested was caricaturing. We enhanced identity information in the face by caricaturing each individual face away from an average face, matched to the target face for sex, race, age, expression, and viewpoint to ensure enhancement specifically of identity information. Previous studies have demonstrated caricatures are better individuated than veridical faces, for high-resolution and blurred photographs. Here we demonstrate this caricature advantage is also present for "phosphenised faces" that simulate prosthetic vision in normal-vision participants. We also place limits on the resolution (number of elements in the prosthetic array) required before caricaturing is beneficial. In a task testing perception of similarity between people, we found that pairs of different-identity faces were rated as more dissimiliar when caricatured than when not. This improvement occurred for 40x40 arrays with no element dropout (better resolution than current bionic eyes implanted in patients), for 40x40 and 32x32 arrays with 30% random element dropout (which may approximate the best current implants). No caricature advantage was found for 16x16 arrays, for which participants were very poor at discerning individual identity. We then tested face memory in an old-new recognition task. Caricaturing improved face memory for 40x40 arrays.

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63.457 **Altered hemispheric specialization for faces and word in developmental dyslexia** Eva Dundas[1](edundas@andrew.cmu.edu), Yafit Gabay[1], David Plaut[1], Marlene Behrmann[1]; [1]Carnegie Mellon University

Extensive evidence gleaned from investigations with adults reveals the existence of highly specialized and seemingly independent neural mechanisms for visual word recognition in the left hemisphere, and for visual face recognition in the right hemisphere (for review, see Toga & Thompson, 2003). Emerging evidence suggests, however, that these two domains are not independent and that word lateralization is driving the emergence of face lateralization (Dundas, Plaut, & Behrmann, 2013; Dehaene et al., 2011) On this account, participants with disrupted organization of word processing should also exhibit altered organization of face processing. The current study examines the hemispheric superiority for faces and words in adults who have been diagnosed with developmental dyslexia, and demonstrate persistent reading difficulties. Using behavioral and neurophysiological measures, we replicate the standard finding of greater accuracy and stronger N170 in the left over the right hemisphere for words, and conversely, greater accuracy and stronger N170 in the right over the left hemisphere for faces in adults without reading difficulty. In adults with developmental dyslexia, however, we did not observe a hemispheric difference in accuracy for words or for faces. Despite showing a stronger N170 in the left over the right hemisphere for words, the N170 for words had longer latency and was more drawn out than it was for adults without reading difficulties. In turn, the adults with developmental dyslexia showed no difference in the strength of the N170 for faces between hemispheres. These findings suggest that the hemispheric organization of face and word processing do not develop independently, and that when there is a failure to develop coherent word processing in the left hemisphere, face processing does not become instantiated in the right hemisphere. A theoretical account in which competition for visual representations unfolds over the course of development is proposed to account for the findings.

63.458 **Alexithymia explains impaired emotion recognition in eating disorders and schizophrenia** Rebecca Brewer[1], Richard Cook[2], Geoffrey Bird[1]; [1]MRC Social, Genetic, and Developmental Psychiatry Centre, Institute of Psychiatry, King's College London, [2]Department of Psychology, City University London

Although contemporary models of face processing suggest that emotion recognition and identity processing dissociate, relying on different neural and cognitive mechanisms, selective deficits in facial emotion processing are not often observed. These are evident, however, in individuals with alexithymia, a subclinical trait characterized by difficulties identifying and describing one's own feelings. Our previous research indicated that, in Autism Spectrum Conditions (ASC), levels of alexithymia, and not autistic symptom severity, predicted participants' ability to recognize others' facial emotion. Alexithymia was unrelated, in individuals with and without ASC, to ability to recognize facial identity. Alexithymia is known to be associated with multiple psychological disorders, but whether it has identical underlying causes, or manifests in the same way, across clinical groups is not yet understood. The present study sought to determine whether alexithymia is associated with selective emotion recognition deficits in individuals with eating disorders and schizophrenia, in the same way as in ASC. Eighty participants with an eating disorder, schizophrenia, or no psychological disorder viewed facial images, presented for 800 ms and obscured by visual noise. Following the presentation of each face, they were prompted to attribute either emotion or identity to the face, in the form of a two-alternative forced choice question e.g. 'Anger: yes or no?'. The level of visual noise was adjusted using an adaptive staircase procedure, in order to determine each participant's tolerance for noise when making identity and emotion judgments. In both populations, alexithymia was found to be predictive of emotion recognition ability, despite being unrelated to identity recognition ability. These results suggest that varying degrees of co-occuring alexithymia might contribute to the equivocal findings of emotion recognition deficits in these conditions. Reporting, and controlling for, levels of co-occuring alexithymia should therefore be regarded as routine practice in future studies of emotion recognition in clinical populations.

63.459 **Greater usage of the left eye causes better facial gender discrimination** Frédéric Gosselin[1](frederic.gosselin@umontreal.ca), Alexandre Coüet-Garand[1], Nicolas Dupuis-Roy[1]; [1]Département de psychologie, Université de Montréal

We recently discovered that the use of the eye located on the left side of the stimuli (henceforth the left eye) was positively correlated with performance. Here, we tested the causality of this link by combining a reinforcement procedure and a classification image technique (i.e. Bubbles). Using these techniques, we first induced the use of the right eye in one group of participants (N=11) and the use of the left eye in another group (N=11), and then examined the impact of these manipulations on performance. Participants completed four training sessions (250 trials/session) of a face-gender categorization task in which the faces of men and women were sampled with an adjustable number of randomly located Gaussian apertures (or bubbles). When their target area was sampled, participants received X points for correct responses and were taken 2X points for incorrect responses. Feedback about earnings was given after each trial. Although the participants remained unaware of the conditioning, classification image analyses revealed that the eye which use was reinforced was more positively correlated with accuracy than any other facial regions in both groups. Critically, the performance—as indexed by the number of bubbles required to reach 75% of correct responses—improved significantly more in the group for which the use of the left eye was reinforced than in the other group. Therefore, greater usage of the left eye causes better facial gender discrimination. We will discuss these findings in the context of hemispheric specialization in the brain.

63.460 **Face Motion Influences Eye Movement Patterns and Face Processing in Children** Steve Perrotta[1](steve_perrotta@live.com), Naiqi Xiao[1], Paul Quinn[2], Jinliang Qin[3], Genyue Fu[4], Liezhong Ge[5], Kang Lee[1]; [1]Applied Psychology and Human Development, University of Toronto, [2]Department of Psychology, University of Delaware, [3]College of Teacher Education, Zhejiang Normal University, [4]Department of Psychology, Zhejiang Normal University, [5]Department of Psychology, Zhejiang Sci-Tech University

Most studies have used static face images as stimuli to examine face processing and recognition. In real-world situations, however, most of the faces we encounter are moving: they are smiling, nodding, speaking, and so forth. Recent behavioral evidence indicates that moving faces facilitate face recognition in infants, adolescents, and adults (Xiao et al., 2013). However, the mechanism of the facilitate effect of facial movement is still unclear, especially in early childhood. The present study therefore examined facial movements' influence in face processing in children at 4 to 6 years of age. We used the composite face effect paradigm and high-frequency eye tracking. In each dynamic face trial, participants were familiarized with a frontal-view moving face, presenting chewing and blinking movements. In the ensuing test phase, participants saw two static composite faces presented on each side of the screen. The composite faces consisted of upper and lower face halves, which belonged to different models. The two face halves were presented either aligned or misaligned. Participants judged which face's upper half was the same person they saw previously. The static face trials were identical to the dynamic trials, except the familiarized face was a static image. Participants' eye movements were recorded during the familiarization and test phases. Consistent with previous dynamic face studies (Xiao et al., 2013), children looked longer at the mouth region and shorter at the eye region during familiarization with dynamic relative to static faces. We also observed that cumulative fixation time for the left eye was positively associated with the composite face effect in the dynamic condition only. In addition, participants' recognition performance was predicted by the relative looking time on the upper face half during familiarization in the dynamic condition. These results suggest that facial movement influences eye movement patterns and face processing in early childhood.

63.461 **Early and late neural correlates of individual differences in fixation-specific face recognition performance** Matthew F. Peterson[1](matt.peterson@psych.ucsb.edu), Charles Or[1], James Elliott[1], Barry Giesbrecht[1], Miguel P. Eckstein[1]; [1]University of California, Santa Barbara

Introduction: Previously we found that face recognition eye movement behavior varies substantially and reliably between individuals, with some preferring to fixate toward the eyes (Upper Lookers; UL) and others toward the nose (Lower Lookers; LL). These differences were found to be systematically related to individual differences in fixation-specific performance: ULs tend to do best when fixating the eyes, while LLs tend to do best when fixating the nose (Peterson & Eckstein, Psychological Science, 2013). The neural mechanisms mediating this relationship are unknown. Feasibly, these effects could arise from differences in domain-general (e.g., acuity/contrast sensitivity in the periphery), or in face-specific (e.g., fixation-specific representations) visual processing. Here we test these possibilities, using EEG to measure the effects of fixation between groups on early visual (domain-general) and face-specific components. Methods: Results from a speeded face identification task were used to classify subjects into two groups: ULs (fixation <1° below eyes) and LLs (fixation <1° above nose tip). EEG was recorded while subjects viewed rapidly intermixed images of houses and faces, with fixation enforced at either the eyes (Upper Fixation; UF) or the nose tip (Lower Fixation; LF) in alternating blocks. Results: LLs and ULs showed substantial differences in early visual components, with the P1 drastically reduced for LLs for faces but not houses, and a main effect of lowered P1 amplitude for UF trials. The later face-specific N170 component showed an interaction between looking group and fixation, such that ULs actually maximized response in LF trials while LLs showed similar responses across fixation. Conclusion: The results suggest that both basic domain-general and face-specific mechanisms may play a role in the interaction between fixation and face recognition ability.

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63.462 **Individual differences in face recognition abilities linked to variations in diagnostic facial information.** Jessica Royer[1](royer.jessica91@gmail.com), Sandra Lafortune[1], Justin Duncan[1,2], Caroline Blais[1], Daniel Fiset[1]; [1]Université du Québec en Outaouais, [2]Université du Québec à Montréal

Face recognition is a complex task on perceptual and cognitive levels. Indeed, significant differences in face recognition abilities exist within the normal population (Duchaine & Nakayama, 2006), and these differences could be accounted for by qualitative and quantitative variations in the perceptual mechanisms associated with face identification. Forty-five participants (18 men; Mage=21.96; SD=3.13) were recruited for this study. The first task consisted of a 1000 trials 2AFC match-to-sample design. Using Bubbles (Gosselin & Schyns, 2001) we investigated whether visual strategies in face recognition differ within a normal population. Bubblized versions of faces were created by sampling facial information at random spatial locations and at five non-overlapping spatial frequency bands. Accuracy was maintained at 75% by adjusting the number of bubbles on a trial-by-trial basis using QUEST (Watson & Pelli, 1983); thus, the number of bubbles reflected the relative ability of the participants. The second task completed by our participants was the Cambridge Face Memory Test + (CFMT+; Russell,

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Duchaine, & Nakayama, 2009), a measure of face recognition ability. Classification images showing the information in the stimuli that correlated with accuracy were constructed by performing a multiple linear regression on the bubbles' locations and accuracy. We constructed one (n=17) for the participants who obtained the best scores on the CFMT+, and one for those (n=13) who obtained the worst scores (0.5 SD above and below the mean, respectively; M=67.54; SD=12.48). A pixel test was applied to each classification image to determine its statistical significance (Zcrit=3.36, p<0.05; corrected for multiple comparisons). Our results indicate that the most skillful participants exclusively use the eye region when identifying faces, whereas the least skillful participants use information stemming from both the region of the eyes and the mouth. These results suggest that differences in perceptual mechanisms of face recognition also exist within the normal population.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada (NSERC)

63.463 **A reciprocal model of face recognition and the autism condition: Evidence from an individual differences perspective** James Tanaka[1](jtanaka@uvic.ca), Drew Halliday[1], Stuart MacDonald[1], Suzanne Scherf[2]; [1]Department of Psychology, University of Victoria, British Columbia, [2]Department of Psychology, The Pennsylvania State University

Although autism spectrum disorder is defined by deficits in communication and social interactions, displays of repetitive stereotypic behaviours and expressions of restricted interests, a large body of evidence has shown that individuals with autism are also selectively impaired in their face processing abilities. Importantly, the connection between autistic traits and face perception has rarely been examined within the typically developing population. In this study, university participants from the social sciences, sciences, and humanities completed a battery of measures that assessed face, object and emotion recognition abilities, general perceptual-cognitive style, and sub-clinical autistic traits (the Autism Quotient (AQ)). Significant correlations were found between AQ scores, and face recognition, gender and science and non-science majors. A hierarchical multiple regression analysis showed that gender, object recognition and AQ scores reliably predicted performance on the face recognition measure, such that males and individuals with autistic-like characteristics, and those with lower object recognition scores performed more poorly on the face recognition test. Conversely, major, gender and face recognition reliably predicted scores on the AQ measure, such that science majors, males, and individuals with poor face recognition skills showed a higher degree of autistic-like traits. Consistent with recent claims, these results support the notion that impaired face recognition abilities may contribute to the key social deficits seen in autism. These findings have important implications for developing Autism interventions focusing on face processing skills.

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63.464 **Narcissistic personality differences in facial emotional expression categorization** Jessica Tardif[1](tarj03@uqo.ca), Daniel Fiset[1], Caroline Blais[1]; [1]Université du Québec en Outaouais

Narcissistic Personality Disorder has been linked to a lack of empathy and a disrupted recognition of facial emotional expressions (Marissen, Deen, & Franken, 2012). To further investigate the link between narcissism and categorization of facial expressions, the performance and visual strategies in facial expression categorization of 20 healthy subjects were assessed using Bubbles (Gosselin & Schyns, 2001) and a separate expression categorization task involving fully-visible faces. The Bubbles task consisted in presenting sparse versions of emotional faces created by sampling facial information at random spatial locations and at five non-overlapping spatial frequency bands. Narcissism levels were evaluated using the Narcissistic Personality Inventory (NPI; Raskin & Hall, 1979). Each participant performed two categorization tasks with 4 facial expressions (anger, disgust, fear, happiness). NPI scores correlated positively with the number of Bubbles needed to maintain performance at 65% (r = 0.4634, p <0.05) and with reaction times in the task involving full faces (r = 0.4977, p <0.05). Classification images (CI) revealing what visual information correlated with participants' accuracy were constructed separately for the most and less narcissistic subjects (z-scores higher than 0.5 or lower than -0.5) by performing a multiple linear regression on the bubbles locations and accuracy. The results shows that CIs for fear differ across groups (Zcrit = 3.36, p <0.05; corrected for multiple comparisons). Both groups use the mouth region but differ on which eye they use: narcissistic subjects using the left one. Our results are congruent with the alteration observed with clinical subjects in the performance at recognizing facial expressions (Marissen, Deen, & Franken, 2011). Furthermore, we show that in a non-clinical sample, the variations in performance are coupled with a different lateralisation bias in the eye utilisation during the processing of the fearful expression.

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