Vision Sciences Society

13th Annual Meeting, May 10-15, 2013

Waldorf Astoria Naples, Naples, 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
1 Friday	1 Early AM talk session	1 Royal Palm 1-3	1, 2, 3... For talks
2 Saturday	2 Late AM talk session	2 Royal Palm 4-5	01, 02, 03... For posters
3 Sunday	3 AM poster session	3 Royal Palm 6-8	
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Examples:
21.16 Saturday, early AM talk in Royal Palm 1-3, 6th talk
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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

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S1 The structure of visual working memory

Friday, May 10, 1:00 - 3:00 pm, Royal Palm 1-3

Organizer: Wei Ji Ma, Baylor College of Medicine

TWO THEORETICAL ISSUES Working memory is an essential component of perception, cognition, and action. The past eight years have seen a surge of activity aimed at understanding the structure of visual working memory. This symposium brings together some of the leading thinkers in this field to discuss two central theoretical issues: slots versus resources, and the role of context. SLOTS VERSUS RESOURCES Working memory is widely believed to be subject to an item limit: no more than a fixed number of items can be stored and any additional items are forgotten. In 2004, Wilken and Ma challenged this notion and advocated for an alternative framework in which a continuous memory resource is divided over all items and errors are explained in terms of the quality of encoding rather than the quantity of remembered items. Since then, arguments have been made on both sides, notably by speakers in this symposium (Luck, Bays, Alvarez, Ma). New concepts that have been introduced in this debate include variable precision, non-target reports, Bayesian inference, and the neural substrate of memory resource. Intriguingly, all speakers have recently used the same visual working memory paradigm – delayed estimation – to draw sometimes conflicting conclusions. Therefore, we expect a vivid exchange of thoughts. THE ROLE OF CONTEXT In the slots-versus-resources debate, items are routinely assumed to be encoded independently in working memory. This assumption is likely to be wrong, but how wrong? Recent work has pointed out the large effects of the context in which an item is presented. Items seem to be remembered in groups or ensembles organized by space or feature, and this introduces predictable biases. Hierarchical Bayesian models have been proposed by the groups of Alvarez and Jacobs to quantify context effects. They will both be speaking about these data and models. TARGET AUDIENCE The symposium aims to present current debates and open questions in the study of visual working memory to a broad audience. We believe this symposium will be of interest to students, postdocs, and faculty. The contents should be useful to a very large VSS audience: anyone studying multiple-object working memory or attention using psychophysics, electrophysiology, modeling, neuroimaging, or EEG/MEG. The symposium could benefit them by suggesting new theoretical frameworks to think about data, as well as new experimental paradigms.

Continuous versus discrete models of visual working memory capacity

Speaker: Steven J. Luck, University of California, Davis

Author: Weiwei Zhang, University of California, Davis

Working memory plays a key role in visual cognition, allowing the visual system to span the gaps created by blinks and saccades and providing a major source of control over attention and eye movements. Moreover, measurements of visual working memory capacity for simple visual features are strongly correlated with individual differences in higher cognitive abilities and are related to psychiatric and neurological disorders. It is therefore critically important that we understand the nature of capacity limits in visual working memory. Two major classes of theories have been proposed, discrete theories in which a limited number of items can be concurrently stored with high resolution, and continuous theories in which a potentially limitless number of items can be stored by reducing the precision of the representations. In this talk, we will review 15 years of research on the nature of visual working memory representations and present new evidence that favors discrete representations.

Continuous resources and variable precision in working memory

Speaker: Wei Ji Ma, Baylor College of Medicine

Authors: Ronald van den Berg, Baylor College of Medicine; Hongsup Shin, Baylor College of Medicine

In comparisons between item-limit and continuous-resource models of working memory, the continuous-resource model tested is usually a stereotyped one in which memory resource is divided equally among items. This model cannot account for human behavior. We recently introduced the notion that resource (mnemonic precision) is variable across items and trials. This model provides excellent fits to data and outperforms item-limit models in explaining delayed-estimation data. When studying change detection, a model of memory is not enough, since the task contains a decision stage. Augmenting the variable-precision model of memory with a Bayesian decision model provides the best available account of change detection performance across set sizes and change magnitudes. Finally, we argue that variable, continuous precision has a plausible neural basis in the gain of a neural population. Our results and those of other groups overhaul long-held beliefs about the limitations of working memory.

Working memory capacity and allocation reflect noise in neural storage

Speaker: Paul M. Bays, University College London

A key claim differentiating "resource" from "slot" models of WM is that resources can be allocated flexibly, enhancing the mnemonic precision of some visual elements at a cost to others. While salient visual events are found to have a short-lived influence on WM that is rapidly suppressed, informative cues lead to a long-lasting reallocation of resources. We argue that resource limits in working memory are a direct consequence of stochasticity (noise) in neural representations. A model based on population coding reproduces the empirical relationship between error distributions and memory load and demonstrates that observers allocate limited neural resources in a near-optimal fashion.

Beyond Slots vs. Resources

Speaker: George Alvarez, Harvard University

Authors: Timothy Brady, Harvard University; Daryl Fougnie, Harvard University; Jordan Suchow, Harvard University

Slot and resource models have been influential in the study of visual working memory capacity. However, several recent empirical findings are not explicitly predicted by either model. These findings include: (1) a shared limit on the fidelity of working memory and long-term memory, (2) stochastic variability in working memory that is not explained by uneven allocation of a commodity such as slots or resources, and (3) the existence of structured representations. Together, these findings demand either significant modification of existing slot and resource models, or the introduction of a new framework for understanding visual working memory capacity.

A Probabilistic Clustering Theory of the Organization of Visual Short-Term Memory

Speaker: Robert Jacobs, University of Rochester

Author: A. Emin Orhan, University of Rochester

Some models of visual short-term memory (VSTM) assume that memories for individual items are independent. Recent experimental evidence indicates that this assumption is false. People's memories for individual items are influenced by the other items in a scene. We develop a Probabilistic Clustering Theory (PCT) for modeling the organization of VSTM. PCT states that VSTM represents a set of items in terms of a probability distribution over all possible clusterings or partitions of those items. Because PCT considers multiple possible partitions, it can represent an item at multiple granularities or scales simultaneously. Moreover, using standard probabilistic inference, it automatically determines the appropriate partitions for the particular set of items at hand, and the probabilities or weights that should be allocated to each partition. A consequence of these properties is that PCT accounts for experimental data that have previously motivated hierarchical models of VSTM, thereby providing an appealing alternative to hierarchical models with pre-specified, fixed structures.

S2 Contextual and top-down influences in vision

Friday, May 10, 1:00 - 3:00 pm, Royal Palm 4-5

Organizer: Uri Polat, Tel-Aviv University

According to classical models of spatial vision, the output of neurons in the early visual cortex is determined by the local features of the stimuli and integrated at later stages of processing (feedforward). However, experimental results obtained during the last two decades show contextual modulation: local perceptual effects are modulated by global image properties. The receptive field properties of cortical neurons are subject to learning and to top-down influences of attention, expectation and perceptual task. Even at early cortical stages of visual processing neurons are subject to contextual influences that play a role in intermediate level vision, contour integration and surface segmentation, which enables them to integrate information over large parts of the visual field. These influences are not fixed but are subject to experience, enabling neurons to encode learned information. The dynamic properties of context modulations are mediated by an interaction between reentrant signals to the cortex and intrinsic cortical connections, changing effective connectivity within the cortical network. The evolving view of the nature of the receptive field includes contextual influences which change in the long term as a result of perceptual learning and in the short term as a result of a changing behavioral context. In the symposia we will present anatomical, physiological and psychophysical data showing contextual effects in lateral interactions, grouping, border ownership, crowding and perceptual learning.

Contextual modulation in the visual cortex

Speaker: Charles Gilbert, The Rockefeller University, New York

Vision is an active process. The receptive field properties of cortical neurons are subject to learning and to top-down influences of attention, expectation and perceptual task. Even at early cortical stages of visual processing neurons are subject to contextual influences that play a role in intermediate level vision, contour integration and surface segmentation, which enables them to integrate information over large parts of the visual field. These influences are not fixed but are subject to experience, enabling neurons to encode learned information. Even in the adult the visual cortex there is considerable plasticity, where cortical circuits undergo exuberant changes in axonal arbors following manipulation of sensory experience. The integrative properties of cortical neurons, the contextual influences that confer selectivity to complex stimuli, are mediated in part by a plexus of long range horizontal connections that enable neurons to integrate information over an area of visual cortex representing large parts of the visual field. These connections are the substrate for an association field, a set of interactions playing a role in contour integration and saliency. The association field is not fixed. Rather, neurons can select components of this field to express difference functional properties. As a consequence neurons can be thought of as adaptive processors, changing their function according to behavioral context, and their responses reflect the demands of the perceptual task being performed. The top-down signal facilitates our ability to segment the visual scene despite its complex arrangement of objects and backgrounds. It plays a role in encoding and recall of learned information. The resulting feedforward signals carried by neurons convey different meanings according to the behavioral context. We propose that these dynamic properties are mediated by an interaction between reentrant signals to the cortex and intrinsic cortical connections, changing effective connectivity within the cortical network. The evolving view of the nature of the receptive field includes contextual influences which change in the long term as a result of perceptual learning and in the short term as a result of a changing behavioral context.

Spatial and temporal rules for contextual modulations

Speaker: Uri Polat, Tel-Aviv University, Tel-Aviv, Israel

Most contextual modulations, such as center-surround and crowding exhibit a suppressive effect. In contrast, collinear configuration is a unique case of contextual modulation in which the effect can be either facilitative or suppressive, depending on the context. Physiological and psychophysical studies revealed several spatial and temporal rules that determine the modulation effect: 1) spatial configuration: collinear configuration can be either facilitative or suppressive, whereas non-collinear configurations may be suppressive; 2) separation between the elements: suppression for close separation that coincides with the size of the receptive field and facilitation outside the receptive field; 3) activity dependent: facilitation for low contrast (near the threshold) and suppression for high contrast; 4) temporal properties: suppression is fast and transient, whereas facilitation is delayed and sustained; 5) attention may enhance the facilitation; 6) slow modulation: perceptual learning can increase the facilitatory effect over a time scale of several days; 7) fovea and periphery: similar rules can be applied when spatial scaling to the size of receptive field is done. It is believed that the role of collinear facilitation is to enhance contour integration and object segmentation, whereas center-surround is important for pop-out. Our recent studies suggest that these rules can serve as a unified model for spatial and temporal masking as well as for crowding.

Border ownership and context

Speaker: Rudiger von der Heydt, The Johns Hopkins University

A long history of studies of perception has shown that the visual system organizes the incoming information early on, interpreting the 2D image in terms of a 3D world, and producing a structure that enables object-based attention and tracking of object identity. Recordings from monkey visual cortex show that many neurons, especially in area V2, are selective for border ownership. These neurons are edge selective and have ordinary classical receptive fields, but in addition, their responses are modulated (enhanced or suppressed) depending on the location of a 'figure' relative to the edge in their receptive field. Each neuron has a fixed preference for location on one side or the other. This selectivity is derived from the image context far beyond the classical receptive field. This talk will review evidence indicating that border ownership selectivity reflects mechanisms of object definition. The evidence includes experiments showing (1) reversal of border ownership signals with change of perceived object structure, (2) border ownership specific enhancement of responses in object-based selective attention,)3) persistence of border ownership signals in accordance with continuity of object perception, and (4) remapping of border ownership signals across saccades and object movements. Some of these findings can be explained by assuming that grouping circuits detect 'objectness' according to simple rules, and, via recurrent projections, enhance the low-level feature signals representing the object. This might be the mechanism of object-based attention. Additional circuits may provide persistence and remapping.

Visual cortical mechanisms for perceptual grouping

Speaker: Pieter Roelfsema, Netherlands Institute for Neuroscience, Amsterdam, the Netherlands

A fundamental task of vision is to group the image elements that belong to one object and to segregate them from other objects and the background. I will discuss a new conceptual framework that explains how the binding problem is solved by the visual cortex. According to this framework, two mechanisms are responsible for binding: base-grouping and incremental grouping. Base-groupings are coded by single neurons tuned to multiple features, like the combination of a color and an orientation. They are computed rapidly because they reflect the selectivity of feedforward connections that propagate information from lower to higher areas of the visual cortex. However, not all conceivable feature combinations are coded by dedicated neurons. Therefore, a second, flexible incremental grouping mechanism is required. Incremental grouping relies on horizontal connections between neurons in the same area and feedback connections that propagate information from higher to lower areas. These connections spread an enhanced response (not synchrony) to all the neurons that code image elements that belong to the same perceptual object. This response enhancement acts as a label that tags those neurons that respond to image elements to be bound in perception. The enhancement of neuronal activity during incremental grouping has a correlate in psychology because object-based attention is directed to the features labeled with the enhanced neuronal response. Our recent results demonstrate that feedforward and feedback processing rely on different receptors for glutamate and on processing in different cortical layers.

Crowding in context

Speaker: Dennis Levi, UC Berkeley

In peripheral vision, objects that can be readily recognized when viewed in isolation, become unrecognizable in clutter. This is the interesting phenomenon known as visual crowding. Crowding represents an essential bottleneck, setting limits on object perception, eye movements, visual search, reading and perhaps other functions in peripheral, amblyopic and developing vision (Whitney & Levi, 2011). It is generally defined as the deleterious influence of nearby contours on visual discrimination, but the effects of crowding go well beyond impaired discrimination. Crowding impairs the ability to recognize and respond appropriately to objects in clutter. Thus, studying crowding may lead to a better understanding of the processes involved in object recognition. Crowding also has important clinical implications for patients with macular degeneration, amblyopia and dyslexia. Crowding is strongly dependent on context. The focus of this talk will be on trying to put crowding into context with other visual phenomena.

Perceptual learning in context

Speaker: Dov Sagi, The Weizmann Institute of Science, Rehovot, Israel

Studies of perceptual learning show a large diversity of effects, with learning rate and specificity varying across stimuli and experimental conditions. Most notably, there is an initial fast phase of within session (online) learning followed by a slower phase, taking place over days, which is highly specific to basic image features. Our results show that the latter phase is highly sensitive to contextual modulation. While thresholds for contrast discrimination of a single Gabor patch are relatively stable and unaffected by training, the addition of close flankers induces dramatic improvements of thresholds, indicating increased gain of the contrast response function ("context enabled learning"). Cross-orientation masking effects can be practically eliminated by practice. In texture discrimination, learning was found to interact with slowly evolving adaptive effects reducing the effects of learning. These deteriorative effects can be eliminated by cross-orientation interactions found to counteract sensory adaptation. The experimental results are explained by plasticity within local networks of early vision assuming excitatory-inhibitory interactions, where context modulates the balance between excitation and inhibition. We suggest that reduced inhibitory effects increases learning efficiency, making learning faster and generalizable. Specificity of learning seems to be the result of experience dependent local contextual interactions.

S3 Active Perception: The synergy between perception and action

Friday, May 10, 1:00 - 3:00 pm, Royal Palm 6-8

Organizers: Michele Rucci, Boston University & Eli Brenner, VU University

Visual perception is often studied in a passive manner. The stimulus on the display is typically regarded as the input to the visual system, and the results of experiments are frequently interpreted without consideration of the observer's motor activity. In fact, movements of the eyes, head or body are often treated as a nuisance in vision research experiments, and care is often taken in minimizing them by properly constraining the observer. Like many other species, however, humans are not passively exposed to the incoming flow of sensory data. Instead, they actively seek useful information by coordinating sensory processing with motor activity. Motor behavior is a key component of sensory perception, as it enables control of sensory signals in ways that simplify perceptual tasks. The goal of this symposium is to make VSS attendees aware of recent advances in the field of active vision. Non-specialists often associate active vision with the study of how vision controls behavior. To counterbalance this view, the present workshop will instead focus on closing the loop between perception and action. That is, we will examine both the information that emerges in an active observer and how this information is used to guide behavior. To emphasize the fact that behavior is a fundamental component of visual perception, this symposium will address the functional consequences of a moving agent from multiple perspectives. We will cover the perceptual impact of very different types of behavior, from locomotion to microscopic eye movements. We will discuss the multimodal sources of information that emerge and need to be combined during motor activity. Furthermore, we will look at the implications of active vision at multiple levels, from the general computational strategies to the specific impact of eye movement modulations on neurons in the visual cortex. Speakers with expertise in complementary areas and with research programs involving a variety of techniques and focusing on different levels of analysis were specifically selected to provide a well-rounded overview of the field. We believe that this symposium will be of interest to all VSS participants, both students and faculty. It will make clear (to students in particular) that motor activity should not be regarded as an experimental nuisance, but as a critical source of information in everyday life. The symposium will start with a general introduction to the topic and the discussion of a specific example of closed sensory-motor loop, the interception of moving objects (Eli Brenner). It will continue discussing the visual information emerging during locomotion and its use in avoiding collisions (John Wann). We will then examine the dynamic strategy by which attention is redirected during grasping (Heiner Deubel), and how even microscopic "involuntary" eye movements are actually part of a closed sensory-motor loop (Michele Rucci). The last two speakers will address how different types of visual information emerging in an active observer are encoded in the retina (Ronen Segev) and in the cortex (Yves Fregnac).

Introduction to active vision: the complexities of continuous visual control

Speaker: Eli Brenner, Human Movement Sciences, VU University

Author: Jeroen Smeets, Human Movement Sciences, VU University

Perception is often studied in terms of image processing: an image falls on the retina and is processed in the eye and brain in order to retrieve whatever one is interested in. Of course the eye and brain analyse the images that fall on the retina, but it is becoming ever more evident that vision is an active process. Images do not just appear on the retina, but we actively move our eyes and the rest of our body, presumably to ensure that we constantly have the best possible information at our disposal for the task at hand. We do this despite the complications that moving sometimes creates for extracting the relevant information from the images. I will introduce some of the complications and benefits that arise from such active vision on the basis of research on the role of pursuing an object with one's eyes when trying to intercept it. People are quite flexible in terms of where they look when performing an interception task, but where they look affects their precision. This is not only due to the inhomogeneity of the retina, but also to the fact that neuromuscular delays affect the combination of information from different sensory modalities. The latter can be overcome by relying as much as possible on retinal information (such as optic flow) but there are conditions in which people do not do so but rely on combinations of retinal and extra-retinal information instead (efferent and afferent information about one's own actions).

Why it's good to look where you are going

Speaker: John Wann, Dept of Psychology, Royal Holloway University of London

The control of direction and avoidance of collision is fundamental to effective locomotion. A strong body of research has explored the use of optic flow and/or eye-movement signals in judging heading. This presentation will outline research on active steering that explores the use of optic flow and eye-movement signals, but where a key aspect of effective control is where you look and when. The talk will also briefly outline studies using fMRI that highlight the neural systems that support the control model proposed from the behavioural research. Although this model is based on principles derived from optical geometry it conveniently converges on the heuristics used in advanced driver/motorcyclist training, and elite cycling, for negotiating bends at speed. Research supported by the UK EPSRC, UK ESRC, EU FP7 Marie Curie.

Motor selection and visual attention in manual pointing and grasping

Speaker: Heiner Deubel, Department Psychologie, Ludwig-Maximilians-Universität München, Germany

Authors: Rene Gilster, Department Psychologie, Ludwig-Maximilians-Universität München, Germany; Constanze Hesse, School of Psychology, University of Aberdeen, United Kingdom

It is now well established that goal-directed movements are preceded by covert shifts of visual attention to the movement target. I will first review recent evidence in favour of this claim for manual reaching movements, demonstrating that the planning of some of these actions establishes multiple foci of attention which reflect the spatial–temporal requirements of the intended motor task. Recently our studies have focused on how finger contact points are chosen in grasp planning and how this selection is related to the spatial deployment of attention. Subjects grasped cylindrical objects with thumb and index finger. A perceptual discrimination task was used to assess the distribution of visual attention prior to the execution of the grasp. Results showed enhanced discrimination for those locations where index finger and thumb would touch the object, as compared to the action-irrelevant locations. A same-different task was used to establish that attention was deployed in parallel to the grasp-relevant locations. Interestingly, while attention seemed to split to the action-relevant locations, the eyes tended to fixate the centre of the to-be-grasped object, reflecting a dissociation between overt and covert attention. A separate study demonstrated that a secondary, attention-demanding task affected the kinematics of the grasp, slowing the adjustment of hand aperture to object size. Our results highlight the import role of attention also in grasp planning. The findings are consistent with the conjecture that the planning of complex movements enacts the formation of a flexible "attentional landscape" which tags all those locations in the visual lay-out that are relevant for the impending action.

The function of microsaccades in fine spatial vision

Speaker: Michele Rucci, Boston University

The visual functions of microsaccades, the microscopic saccades that humans perform while attempting to maintain fixation, have long been debated. The traditional proposal that microsaccades prevent perceptual fading has been criticized on multiple grounds. We have recently shown that, during execution of a high-acuity task, microsaccades move the gaze to nearby regions of interest according to the ongoing demands of the task (Ko et al., Nature Neurosci. 2010). That is, microsaccades are used to examine a narrow region of space in the same way larger saccades normally enable exploration of a visual scene. Given that microsaccades keep the stimulus within the fovea, what is the function of these small gaze relocations? By using new gaze-contingent display procedures, we were able to selectively stimulate retinal regions at specific eccentricities within the fovea. We show that, contrary to common assumptions, vision is not uniform within the fovea: a stimulus displacement from the center of gaze of only 10 arcmin already causes a significant reduction in performance in a high-acuity task. We also show that precisely-directed microsaccades compensate for this lack of homogeneity giving the false impression of uniform foveal vision in experiments that lack control of retinal stimulation. Finally, we show that the perceptual improvement given by microsaccades in high-acuity tasks results from accurately positioning the preferred retinal locus in space rather than from the temporal transients microsaccades generate. These results demonstrate that vision and motor behavior operate in a closed loop also during visual fixation.

Decorrelation of retinal response to natural scenes by fixational eye movements

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

Fixational eye movements are critical for vision since without them the retina adapts fast to a stationary image and the entire visual perception fades away in a matter of seconds. Still, the connection between fixational eye movements and retinal encoding is not fully understood. To address this issue, it was suggested theoretically that fixational eye movements are required to reduce the spatial correlations which are typical for natural scenes. The goal of our study was to put this theoretical prediction under experimental test. Using a multi electrode array, we measured the response of the tiger salamander retina to movies which simulated two types of stimuli: fixational eye movements over a natural scene and flash followed by static view of a natural scene. Then we calculated the cross-correlation in the response of the ganglion cells as a function of receptive field distance. We found that when static natural images are projected, strong spatial correlations are present in the neural response due to correlation in the natural scene. However, in the presence of fixational eye movements, the level of correlation in the neural response drops much faster as a function of distance which results in effective decorrelation of the channels streaming information to the brain. This observation confirms the prediction that fixational eye movement act to reduce the correlations in retinal response and provides better understanding of the contribution of fixational eye movements to the information processing by the retina.

Searching for a fit between the "silent" surround of V1 receptive fields and eye-movements

Speaker: Yves Frégnac, UNIC-CNRS Department of Neurosciences, Information and Complexity Gif-sur-Yvette, France

To what extent emerging macroscopic perceptual features (i.e., Gestalt rules) can be predicted in V1 from the characteristics of neuronal integration? We use on vivo intracellular electrophysiology in the anesthetized brain, but where the impact of visuomotor exploration on retinal flow is controlled by simulating realistic but virtual classes of eye-movements (fixation, tremor, shift, saccade). By comparing synaptic echoes to different types of full field visual statistics (sparse noise, grating, natural scene, dense noise, apparent motion noise) in which the retinal effects of virtual eye-movements is, or is not, included, we have reconstructed the perceptual association field of visual cortical neurons extending 10 to 20° away from the classical discharge field. Our results show that there exists for any V1 cortical cell a fit between the spatio-temporal organization of its subthreshold "silent" (nCRF) and spiking (CRF) receptive fields with the dynamic features of the retinal flow produced by specific classes of eye-movements (saccades and fixation). The functional features of the resulting association field are interpreted as facilitating the integration of feed-forward inputs yet to come by propagating some kind of network belief of the possible presence of Gestalt-like percepts (co-alignment, common fate, filling-in). Our data support the existence of global association fields binding Form and Motion, which operate during low-level (non attentive) perception as early as V1 and become dynamically regulated by the retinal flow produced by natural eye-movements. Current work is supported by CNRS, and grants from ANR (NatStats and V1-complex) and the European Community FET-Bio-I3 programs (IP FP6: FACETS (015879), IP FP7: BRAINSCALES(269921) and Brain-i-nets (243914)).

S4 ARVO@VSS: Visual Development

Friday, May 10, 3:30 - 5:30 pm, Royal Palm 1-3

Organizers: Susana Chung, University of California, Berkeley and Anthony Norcia, Stanford University

Many visual functions continue to develop and reach adult levels only in late childhood. The successful development of normal visual functions requires 'normal' visual experience. The speakers of this symposium will review the time courses of normal visual development of selected visual functions, and discuss the consequences of abnormal visual experience during development on these visual functions. The prospect of recovering visual functions in adults who experienced abnormal visual experience during development will also be discussed, along with the advances made in the assessment of visual functions in children with abnormal visual development due to damage to the visual cortex and the posterior visual pathways.

Postnatal development of early visual cortex in macaque monkeys

Speaker: Yuzo Chino, University of Houston

Our recent studies have demonstrated that the cortical circuitry supporting the monocular and binocular RF properties of V1 and V2 neurons in macaque monkeys is qualitatively adult like as early as 4 weeks of age, and, if not, by 8 weeks of age. However the functional organization of visual cortex in neonates and infants is fragile and needs 'normal' visual experience to complete its postnatal development. Experiencing binocular imbalance soon after birth disrupts this development and can result in binocular vision anomalies and often amblyopia. What happens to the visual brain of amblyopic subjects that experience early binocular imbalance is not well understood except for some aspects of early monocular form deprivation. This talk will present the results of studies in primate models of strabismic and anisometropic amblyopia, and make a proposal on how some of monocular deficits in amblyopes may develop. Our earlier studies established that binocular imbalance in infant monkeys immediately initiates interocular suppression in their visual cortex, which persists until adulthood. We also found that the depth of amblyopia in individual strabismic monkeys is highly correlated with the strength of binocular suppression in V1 and V2. I will present our preliminary data to demonstrate that such robust binocular suppression can disrupt the functional development of cortical circuits supporting the spatial map of subunits within the receptive field of a given V2 neuron in amblyopic monkeys, and also, suppression may affect the timing and reliability of spiking by these neurons.

Postnatal development of form and motion pathways in macaque monkeys

Speaker: Lynne Kiorpes, New York University

Many visual functions are poor in infant primates and develop to adult levels during the early months and years after birth. Basic visual processes and those that are higher-order develop over different time courses. These later developing aspects of vision are those that require the integration of information over space (such as contour integration) or space-time (such as global motion or pattern motion discrimination), and likely depend at least in part on the maturation of extrastriate visual areas. Moreover, these developmental programs can be modified by visual experience, with the later developing functions showing greater vulnerability to abnormal visual experience. This talk will describe the development of global form and motion perception, highlight the influence of abnormal visual experience and discuss underlying neural correlates.

Removing the brakes on brain plasticity in adults with amblyopia

Speaker: Dennis Levi, University of California, Berkeley

Experience-dependent plasticity is closely linked with the development of sensory function. Beyond this sensitive period, developmental plasticity is actively limited; however, new studies provide growing evidence for plasticity in the adult visual system. The amblyopic visual system is an excellent model for examining the "brakes" that limit recovery of function beyond the critical period. While amblyopia can often be reversed when treated early, conventional treatment is generally not undertaken in older children and adults. However new clinical and experimental studies in both animals and humans provide evidence for neural plasticity beyond the critical period. The results suggest that perceptual learning and video game play may be effective in improving a range of visual performance measures and importantly the improvements may transfer to better visual acuity and stereopsis. These findings, along with the results of new clinical trials, suggest that it might be time to re-consider our notions about neural plasticity in amblyopia.

Assessing visual functions in children with cortical visual impairment

Speaker: Gunilla Haegerstrom-Portnoy, University of California, Berkeley

CVI (cortical or cerebral visual impairment) refers to bilateral reduction in vision function due to damage to the visual cortex and/or the posterior visual pathways in the absence of ocular pathology. CVI is the most common cause of bilateral severe visual impairment in children in the developed world. The causes include hypoxic–ischemic brain damage, head injury (such as shaken baby syndrome), infection, hydrocephalus and metabolic disorders. CVI occurs commonly in premature infants and is often accompanied by cerebral palsy, quadraplegia, seizure disorders and developmental delay. Assessment of vision function in children with CVI is a challenge. Preferential looking methods and sweep VEP methods can be used sucessfully and in our population of children with CVI show an enormous range of values of visual acuity (20/50 to 20/800 VEP grating acuity) and contrast sensitivity (1.3 to 25% Michelsen contrast). Large discrepancies often occur between behavioral and VEP measures of function (often a factor of 10 or more). Longitudinal follow-up of 39 children with CVI over 6.5 years on average demonstrated significant improvement in about 50% of the patients and showed that early VEP measures can predict later behavioral vision function. Improvement in vision function occurred over a surprisingly long time (into the teens).

S5 Decoding and the spatial scale of cortical organization

Friday, May 10, 3:30 - 5:30 pm, Royal Palm 4-5

Organizers: Jeremy Freeman, New York University; Elisha P. Merriam, Departments of Psychology and Neural Science, New York University; and Talia Konkle, Department of Psychology, Harvard University

With the advent of functional neuroimaging (fMRI), hemodynamic responses can be measured over the whole brain with relatively high spatial precision. A formidable challenge, however, is that fMRI responses appear to reflect a multitude of signals, both neural and non-neural, at multiple spatial scales. At times, evidence for multiple scales appears to border on contradiction, e.g. suggesting that the same stimulus dimension is encoded both through both coarse-scale topographic organization and fine-scale columnar structure. A diversity of analyses and methods have highlighted a set of key questions: First, over what expanse of cortex is information meaningfully represented — to what degree is cortical function clustered, if there is clustering at all? Second, if information can be decoded from patterns of fMRI response, what should we infer about the corresponding brain region — does it imply fine-scale structure, or reflect coarse-scale topography? Finally, and crucially, how does the spatial scale of fMRI selectivity reflect the tuning of the underlying neurophysiological signals — does it reflect spikes, field potentials, hemodynamic events, or a complex combination of all three? In this symposium, we have brought together six investigators who are pushing the cutting edge both analytically and methodologically to characterize the spatial structure of visual representation in cortex. Four investigators apply novel multivariate analytical approaches to fMRI data from humans, studying the representation of both low-level features (orientation) and complex objects; our fifth investigator studies the biophysics of the fMRI response using high-resolution fMRI in conjunction with other imaging modalities; and our final investigator records electrophysiological signals from macaques using multi-electrode arrays, a technique that may shed important light on what the fMRI signal reflects. Each talk will introduce the analysis method and experimental approach, and what it has revealed about neural organization, with a critical examination of (i) what is assumed and tested about the spatial scale of the neural response; (ii) what the analysis method can and cannot reveal about the nature of the underlying representations; (iii) what the analysis implies about other, complementary measurements of brain activity. Lively moderated discussions will emphasize points of agreement — or disagreement — across the different approaches. Combined, these talks demonstrate the richness of representational structure at multiple spatial scales across the cortex, and highlight the inferential strengths and weaknesses of current analyses, and the benefits of integrating information across multiple experimental techniques. This symposium should attract all investigators and students studying vision using fMRI and decoding (alongside associated behavioral measures), which is a rapidly growing contingent of the VSS community. The particular controversies about decoding and spatial scale that we plan to address have attracted large audiences at recent VSS meetings. Furthermore, due to its inter-disciplinary nature, the symposium is likely to attract investigators and students using a range of experimental techniques, including fMRI and electrophysiology, and motivate them to find new ways to combine these techniques through collaboration.

Orientation decoding in humans — evidence for a columnar contribution?

Speaker: Elisha P. Merriam, Department of Psychology and Neural Science, New York University

Authors: Jeremy Freeman, Departments of Psychology and Neural Science, New York University; David J. Heeger, Departments of Psychology and Neural Science, New York University

The representation of orientation in primary visual cortex (V1) has been examined extensively at a fine spatial scale corresponding to the columnar architecture. In humans, orientation can be decoded from functional magnetic resonance imaging (fMRI) signals using multivariate classification methods, but it is unknown whether orientation decoding depends on the fine-scale, columnar architecture in cortex. We have shown that orientation is also represented in human cortex at a coarse spatial scale, and we have argued that this organization provides the basis for orientation decoding (Freeman et al., 2011). This topic remains highly controversial, and several labs have provided new evidence suggesting that a columnar-scale signal is present in fMRI measurements at conventional resolution. In this talk, I will review the evidence for and against a columnar contribution to orientation decoding. I will present recent evidence from our lab in which we measure fMRI responses in V1 to a variety of spatially structured stimuli — including oriented gratings with different spatial configurations and logarithmic spirals — and apply decoding and spatial filtering analyses to the data. Together, the results of our analyses strongly suggest that orientation decoding does not reflect the irregular spatial arrangements of orientation columns. Rather, it is likely that the coarse-scale topographic map of orientation in V1 is the major, if not the only, source of information that is exploited by multivariate decoding methods.

Underlying sources for decoding of oriented gratings in fMRI

Speaker: Seong-Gi Kim, Department of Neurobiology, University of Pittsburgh

Author: Amir Shmuel, Department of Neurobiology, McGill University

Multivariate machine learning algorithms were applied to BOLD fMRI data obtained from human subjects for decoding the orientation of gratings, with voxels larger than the width of orientation columns. Contributions to this successful decoding using low-resolution BOLD fMRI can potentially be made by 1) functionally selective large blood vessels, 2) orientation bias in large-scale organization, and 3) local orientation irregularities. In order to examine this issue, we re-analyzed cerebral blood volume-weighted fMRI data from cat visual cortex (Fukuda et al., J. of Neurosci, 2006). To remove large vessel contributions, ferrous iron oxide contrast agent was injected into blood. The functional data were obtained with 0.156 x 0.156 x 1 mm3. Then, high-resolution data were down-sampled to low-resolution up to 3 mm (the average orientation cycle is 1.0-1.4 mm). Linear support vector machine analysis showed that the presented orientation can be predicted above the chance level, even at 3-mm voxel resolution. To separate contributions from local orientation irregularities and from large-scale organizations, data were band-pass filtered with center frequency of 0.4 cycles/mm (frequency range of local irregularities) and 0.1 cycles/mm (low frequency). In both conditions, the presented orientation can be predicted above the chance level, with slightly better accuracy for the spatial filter of higher frequencies. Our analysis indicates that 1) large vessel contribution is not essential, and 2) local orientation irregularities can contribute for decoding of orientations in low-resolution fMRI data.

The relationship between the local field potential and spiking activity in primary visual cortex

Speaker: Adam Kohn, Albert Einstein College of Medicine

Author: Xiaoxuan Jia, Albert Einstein College of Medicine

The local field potential (LFP) represents the summed electrical activity in a local region of cortex. It provides a mesoscopic view of network activity and function, between local measures such as single unit spiking activity and more global measures such as BOLD-fMRI and EEG. However, the relationship between the LFP and these signals remains unclear, making it difficult to relate findings across scales of study. We therefore investigated how the LFP is related to spiking activity in primary visual cortex of macaque monkeys, and found a flexible relationship for the gamma frequency components of the LFP. Small sinusoidal gratings, and those masked with noise, induce gamma power that is tuned similarly to spiking activity. Large gratings induce a 'global' gamma rhythm characterized by a distinctive spectral bump. This signal is well tuned for orientation and spatial and temporal frequency, but with a preference that is similar across millimeters of cortex. The preference of this gamma is sensitive to adaptation and the location of a stimulus in visual space. We argue that these properties indicate the global gamma rhythm reflects and magnifies an underlying bias in the neuronal representation of visual stimuli in V1. Our results show that there is not a single, fixed neuronal ensemble contributing to gamma and that the global gamma rhythm may be a useful signal for detecting and characterizing biased representations in visual cortex.

Macro-organization of object responses in occipito-temporal cortex

Speaker: Talia Konkle, Department of Psychology, Harvard University

Author: Alfonso Caramazza, Department of Psychology, Harvard University

What are the dimensions that organize object representation? A common assumption is that the mosaic of category-selective areas are the only large-scale clusters, while the remaining object responses have more heterogenous response profiles with structure primarily at a finer spatial scale. In contrast, I will present results showing a large-scale of object responses spanning the entire ventral and lateral occipito-temporal cortex, based on the dimensions of animacy and size. Zones with systematic animacy-size preferences are arranged in a spoked organization emanating from the occipital pole along a single ventral-medial-to-lateral-to-dorsal-medial axis, bearing marked similarity to the organization of early visual areas. Regions selective for faces, bodies, and scenes fit within these zones, demonstrating consistent meso-scale structure. These results suggest that object cortex, just like early visual cortex, has structure that can be explained at multiple spatial scales. I will argue that understanding this multi-scale representation is valuable for inferring the nature of the underlying cognitive architecture.

High-resolution fMRI reveals cortical tiling of face and limb selectivity in human high-level visual cortex

Speaker: Kalanit Grill-Spector, Department of Psychology and Neuroscience Institute, Stanford University

Author: Kevin Weiner, Department of Psychology, Stanford University

Functional magnetic resonance imaging (fMRI) studies identify areas responding selectively to images of faces and body parts compared to a variety of control objects throughout ventral temporal and lateral occipitotemporal cortices (VTC and LOTC, respectively). Previous research indicates that the location of each region is variable relative to both gross anatomical landmarks, as well as to other high-level visual areas. Using higher-resolution fMRI scanning methods, we conducted a series of experiments revealing that the fine-scale spatial organization of face and limb selectivity is much more consistent than once thought. These experiments reveal a topographic organization of face- and limb-selective regions extending from LOTC to VTC where each high-level region is defined by a combination of anatomical and functional boundaries separating them from neighboring regions just millimeters away. We propose a multi-factor organization framework resulting from these empirical measurements where any region in human high-level visual cortex can be defined using the following criteria: 1) precise anatomical location, 2) preserved spatial relationship among functional regions, 3) preserved relationship relative to known visual field maps, and 4) reliable functional differences among regions. Methodologically, we demonstrate how these organizational features allow consistent parcellation of cortical regions across subjects. Theoretically, we refer to this inter-related structure of multiple maps as cortical tiling and hypothesize that tiling is a universal organizational strategy of the brain. Finally, we discuss computational benefits of this organization serving to accommodate multidimensional information in a concentrated neural territory to increase the repertoire, flexibility, and efficiency of visual processing.

Exploring the scale of common dimensions of information coding in ventral temporal cortex

Speaker: J. Swaroop Guntupalli, Department of Psychological and Brain Sciences, Dartmouth College

Authors: Andrew C. Connolly, Department of Psychological and Brain Sciences, Dartmouth College; James V. Haxby, Department of Psychological and Brain Sciences, Dartmouth College, Center for Mind/Brain Sciences, Universita degli studi di Trento

Scale of representation can refer to either categorical (super-ordinate vs sub-ordinate) or spatial (coarse-scale topographies, fine-scale topographies). Typically, we assume that they map one-to-one – coarse-scale categorical distinctions (animate vs inanimate) are reflected in coarse-scale topographies (medial vs lateral ventral temporal cortex (VT)). This is reflected in the fact that we can use a common decoding model to classify super-ordinate categories (houses vs faces) across-subjects, but fine-scale categorical distinctions (human faces vs animal faces) require individually tailored decoding models. We proposed a method that aligns representations, even at fine-scale, across subjects into common dimensions of encoding in VT. We showed that about 35 orthogonal dimensions are required to decode movie scenes, faces and objects, and 6 animal species from VT. This suggests that category decoding models reveal at least more than two dozen categorical dimensions in VT. Now the question remains: are these common categorical dimensions represented in large-scale cortical topographies? Decoding super-ordinate & sub-ordinate categorical information from a localized cortical patch after removing the low-frequency information can elucidate the spatial scale of representation of both coarse & fine- scale categorical information. We use PCA or MDS to identify common coarse-scale categorical dimensions and decode fine-scale categorical information both on those coarse dimensions and from the space orthogonal to those dimensions across different spatial frequency bands. This can elucidate the scale of representation of fine-scale information both categorically & spatially. We present results of both these analyses in VT on our studies using movies, faces and objects, and animal species.

S6 Does appearance matter?

Friday, May 10, 3:30 - 5:30 pm, Royal Palm 6-8

Organizer: Sarah R. Allred, Rutgers--The State University of New Jersey

Vision science originated with questions about how and why things look the way do. With the advent of physiological tools and the development of rigorous psychophysical methods, however, the language of appearance has been largely abandoned. As scientists, we rarely invoke or report on the qualities of visual appearance and instead report more objective measures such as discrimination thresholds or points of subjective equality. This is not surprising; after all, appearance is experienced subjectively, and the goal of science is objectivity. Thus, phenomenology is sometimes given short shrift in the field as a whole. Here we offer several views, sometimes disparate, grounded in both experimental data and theory, on how vision science is advanced by incorporating phenomenology and appearance. We discuss the nature of scientifically objective methods that capture what we mean by appearance, and the role of subjective descriptions of appearance in vision science. Between us, we argue that by relying on phenomenology and the language of appearance, we can provide a parsimonious framework for interpreting many empirical phenomena, including instructional effects in lightness perception, contextual effects on color constancy, systematic biases in egocentric distance perception and predicting 3D shape from orientation flows. We also discuss contemporary interactions between appearance, physiology, and neural models. Broadly, we examine the criteria for the behaviors that are best thought of as mediated by reasoning about appearances. This symposium is timely. Although the basic question of appearance has been central to vision science since its inception, new physiological and psychophysical methods are rapidly developing. This symposium is thus practical in the sense that these new methods can be more fully exploited by linking them to phenomenology. The symposium is also of broad interest to those interested in the big picture questions of vision science. We expect to pull from a wide audience: the speakers represent a range of techniques (physiology, modeling, psychophysics), a diversity of institutional affiliations and tenure, and similarly broad areas of focus (e.g. cue integration, distance perception, lightness perception, basic spatial and color vision, and higher level color vision).

Legitimate frameworks for studying how things look

Speaker: Benjamin T. Backus, Graduate Center for Vision Research, SUNY College of Optometry

What scientific framework can capture what we might mean by "visual appearance" or "the way things look"? The study of appearance can be operationalized in specific situations, but a general definition is difficult. Some visually guided behaviors, such as changing one's pupil size, maintaining one's upright posture, ducking a projectile, or catching an object when it rolls off the kitchen counter, are not mediated by consciously apprehended appearances. These behaviors use vision in a fast, stereotyped, and automatic way. Compare them to assessing which side of a mountain to hike up, or whether a currently stationary object is at risk of rolling off the counter. These are behaviors probably are mediated by appearance, in the sense of a general-purpose representation that makes manifest to consciousness various estimated scene parameters. One can reason using appearances, and talk about them with other people. Over the years various strategies have been employed to study or exploit appearance: recording unprompted verbal responses from naïve observers; using novel stimuli that cannot be related to previous experience; or using of stimuli that force a dichotomous perceptual decision. We will review these ideas and try to identify additional criteria that might be used. An important realization for this effort is that conscious awareness need not be all-or-none; just as visual sense data are best known at the fovea, appearance is best known at the site of attentional focus.

Why do things seem closer than they are?

Speaker: Frank H. Durgin, Swarthmore College

Author: Zhi Li; Swarthmore College

Systematic and stable biases in the visual appearance of locomotor space may reflect functional coding strategies for the sake of more precisely guiding motor actions. Perceptual matching tasks and verbal estimates suggest that there is a systematic underestimation of egocentric distance along the ground plane in extended environments. Whereas underestimation has previously been understood as a mere failure of proper verbal calibration, such an interpretation cannot account for perceptual matching results. Moreover, we have observed that the subjective geometry of distance perception on the ground plane is quantitatively consistent with the explicit overestimation of angular gaze declination which we have measured independently of perceived distance. We suggest that there is a locally-consistent expansion of specific angular variables in visual experience that is useful for action, and that this stable expansion may aid action by retaining more precise angular information, despite the information being mis-scaled approximately linearly. Actions are effective in this distorted perceived space by being calibrated to their perceived consequences (but notice that this means that measuring spatial action parameters, such as walked distance, are not directly informative about perceived distance). We distinguish our view from reports of small judgmental biases moderated by semantic, social and emotional factors on the one hand (which might or might not involve changes in visual appearance) and also from the prevailing implicit assumption that the perceptual variables guiding action must be accurate. The perceptual variables guiding action must be stable in order to support action calibration and precise to support precise action. We suggest that the systematic biases evident in the visual (and haptic) phenomenology of locomotor space may reflect a functional coding strategy that can render actions that are coded in the same perceived space more effective than if space were perceived veridically.

How expectations affect color appearance and how that might happen in the brain

Speaker: Michael Rudd, Howard Hughes Medical Institute; University of Washington

The highest luminance anchoring principle (HLAP) asserts the highest luminance surface within an illumination field appears white and the lightness of other surfaces are computed relative to the highest luminance. HLAP is a key tenet of the anchoring theories of Gilchrist and Bressan, and Land's Retinex color constancy model. The principle is supported by classical psychophysical findings that the appearance of incremental targets is not much affected by changes in the surround luminance, while the appearances of decremental targets depends on the target-surround luminance ratio (Wallach, 1948; Heinemann, 1955). However, Arend and Spehar (1993) showed that this interpretation is too simplistic. Lightness matches made with such stimuli are strongly affected by instructions regarding either the perceptual dimension to be matched (lightness versus brightness) or the nature of illumination when lightness judgments are made. Rudd (2010) demonstrated that instructional effects can even transform contrast effects into assimilation effects. To model these results, I proposed a Retinex-like neural model incorporating mechanisms of edge integration, contrast gain control, and top-down control of edge weights. Here I show how known mechanisms in visual cortex could instantiate the model. Feedback from prefrontal cortex to layer 6 of V1 modulates edge responses in V1 to reorganize the edge integration properties of the V1-V4 circuit. Filling-in processes in V4 compute different lightnesses depending on the V1 gain settings, which are controlled by the observer's conscious intention to view the stimulus in one way or another. The theory accounts for the instruction-dependent shifts between contrast and assimilation.

How things look

Speaker: Alan Gilchrist, Rutgers - Newark

Recognizing the historical role of materialism in the advancement of modern science, psychology has long sought to get the ghosts out of its theories. Phenomenology has thus been given short shrift, in part because of its distorted form under the early sway of introspectionism. However, phenomenology can no more be avoided in visual perception than the nature of matter can be avoided in physics. Visual experience is exactly what a theory of perception is tasked to explain. If we want to answer Koffka's question of why things look as they do, a crucial step is the description of exactly how things do look. Of course there are pitfalls. Because we cannot measure subjective experience directly, we rely heavily on matching techniques. But the instructions to subjects must be carefully constructed so as to avoid matches based on the proximal stimulus on one hand, and matches that represent cognitive judgments (instead of the percept) on the other. Asking the subject "What do you think is the size (or shade of gray) of the object?" can exclude a proximal stimulus match but it risks a cognitive judgment. Asking "What does the size (or shade of gray) look like?" can exclude a cognitive judgment but risks a proximal match. Training subjects on the correct nature of the task may represent the best way to exclude proximal stimulus matches while the use of indirect tasks may represent the best way to exclude cognitive judgments. Though there may be no perfect solution to this problem, it cannot be avoided.

Phenomenology and neurons

Speaker: Qasim Zaidi, Graduate Center for Vision Research, SUNY College of Optometry

Frequent pitfalls of relying solely on visual appearances are theories that confuse the products of perception with the processes of perception. Being blatantly reductionist and seeking cell-level explanations helps to conceive of underlying mechanisms and avoid this pitfall. Sometimes the best way to uncover a neural substrate is to find physically distinct stimuli that appear identical, while ignoring absolute appearance. The prime example was Maxwell's use of color metamers to critically test for trichromacy and estimate the spectral sensitivities of three classes of receptors. Sometimes it is better to link neural substrates to particular variations in appearance. The prime example was Mach's inference of the spatial gradation of lateral inhibition between neurons, from what are now called Mach-bands. In both cases, a theory based on neural properties was tested by its perceptual predictions, and both strategies continue to be useful. I will first demonstrate a new method of uncovering the neural locus of color afterimages. The method relies on linking metamers created by opposite adaptations to shifts in the zero-crossings of retinal ganglion cell responses. I will then use variations in appearance to show how 3-D shape is inferred from orientation flows, relative distance from spatial-frequency gradients, and material qualities from relative energy in spatial-frequency bands. These results elucidate the advantages of the parallel extraction of orientations and spatial frequencies by striate cortex neurons, and suggest models of extra-striate neural processes. Phenomenology is thus made useful by playing with identities and variations, and considering theories that go below the surface.

The perceptual quality of colour

Speaker: Anya Hurlbert, Institute of Neuroscience, Newcastle University

Colour has been central to the philosophy of perception, and has been invoked to support the mutually opposing views of subjectivism and realism. Here I demonstrate that by understanding color as an appearance, we can articulate a sensible middle ground: although colour is constructed by the brain, it corresponds to a real property of objects. I will argue here that (1) color is a perceptual quality, a reading of the outside world, taken under biological and environmental constraints, and a meaningful property in the perceiver's internal world (2) the core property of colour constancy makes sense only if colour is subjective and (3) measuring colour constancy illustrates both the need for and the difficulty of subjective descriptions of appearance in vision science. For example, colour names give parsimonious descriptions of subjective appearance, and the technique of colour naming under changing illumination provides a reliable method for measuring colour constancy which is both objective and subjective at the same time. In measurements of simultaneous chromatic contrast, responses of "more red" or "more green" are also appearance descriptors which can be quantified. Achromatic adjustment methods ("adjust the patch until it appears white") also map a physical stimulus to the subjective experience of neutrality. I will compare the results of such techniques with our recent measurements of colour constancy using techniques that do not rely on appearance descriptors, in particular, the measurement of discrimination thresholds for global illumination change in real scenes.

Friday Evening Posters

Visual memory: Mechanisms and models

Friday, May 10, 5:30 - 8:00 pm

Poster Session, Orchid Ballroom

16.401 **The impact of distractors on visual short-term memory representation in early visual areas** Katherine Bettencourt[1](kcb@wjh.harvard.edu), Yaoda Xu[1]; [1]Department of Psychology, Harvard University

Visual short-term memory (VSTM) has been shown to recruit a network of brain regions, including frontal, parietal, and posterior sensory regions. Among these brain regions, the fMRI response amplitude of human parietal cortex has been shown to track the amount of visual information held in VSTM, indicating that this brain region plays a role in VSTM information storage. Separately, recent studies using fMRI multivariate pattern analysis (MVPA) have revealed that delay period activity within early visual cortex reflects the contents of VSTM, showing that early visual areas can also contribute to VSTM information storage. However, the results from early visual areas have been obtained, thus far, in the absence of visual distraction. Given the ubiquitous presence of distractors in everyday visual perception, it is crucial to understand whether early visual areas still retain visual information in VSTM under distraction. Here, in an fMRI study using MVPA, we show that while a particular orientation held in VSTM can be successfully decoded from early visual areas in the absence of distractors, decoding performance drops to chance levels when distractors are introduced during the delay period. Importantly, behavioral performance is equally good with and without distractors, showing that the failure to decode in early visual areas under distraction cannot be attributed to poor task performance. In contrast, decoding performance in parietal regions is significantly above chance regardless of whether distractors are present or not. These results indicate that parietal regions likely play a central role in VSTM information storage across a variety of stimulus conditions. In the absence of distraction, early visual areas can be recruited to aid the maintenance of memory representations, likely via a visual rehearsal mechanism. However, such contributions may not be essential for VSTM information storage, especially in the real world where observers typically receive constant visual input.

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16.402 **Task-evoked pupillary responses in iconic memory** Sylvia Guillory[1](sylvia.guillory001@umb.edu), Erik Blaser[1], Luke Eglington[1], Zsuzsa Kaldy[1]; [1]Developmental and Brain Sciences, University of Massachusetts, Boston

Introduction: Task-evoked pupillary responses (TEPR) are a reliable measure of cognitive effort (Beatty, 1982). They vary systematically with working memory load (Kahneman & Beatty, 1966), up to a ceiling, when working memory capacity is reached (Granholm, et al., 1996). Our aim was to investigate whether the same pattern holds for in iconic memory. Methods: In each trial, five expert observers were presented with a set of differently-colored star-shaped items, spaced symmetrically around central fixation. Trials were blocked by set size, with either 4, 6, 8, or 10 items presented. After a 1000 ms exposure, a randomly chosen pair of neighboring items disappeared; this amounts to a zero-latency partial report post-cue. After 500 ms, the two items reappeared, with one changed to a new color and the other unchanged. Participants were instructed to look at the item that changed. Eye movements and pupil diameters were collected throughout the trial by a Tobii T120 eye tracker. Results and conclusions: When set size is below iconic memory capacity, performance on this task should be maximal. As set size exceeds capacity, performance should drop. Indeed, performance was near ceiling for up to 6 items, then started to decrease, pointing to a capacity of 6 items (see Blaser & Kaldy, 2010). However, unlike load-dependent TEPRs that were found in the working memory literature, TEPRs in this task did not increase with set size. In addition to this, there were no significant differences in TEPR between correct and incorrect trials (in set size 10), indicating that errors were caused by failures of memory retrieval, not effort. In short, increasing the load on iconic memory does not result in a concomitant pupil increase, suggesting that these increasing demands do not draw on the same set of cognitive resources demanded by working memory.

Acknowledgement: his research was supported by National Institutes of Health Grant 2R15EY017985 awarded to E. B. and Z. K.

16.403 **Disengagement of Sensory Regions During the Maintenance of Abstract Information in Working Memory** Akiko Ikkai[1](akiko.ikkai@gmail.com), Balaji Lakshmanan[4], Susan Courtney[1,2,3]; [1]Department of Psychological and Brain Sciences, Johns Hopkins University, [2]Department of Neuroscience, Johns Hopkins University, [3]F.M. Kirby Research Center for Functional Brain Imaging, Kennedy Krieger Institute, [4]Department of Neurology and Developmental Medicine, Kennedy Krieger Institute

Previous studies have shown that concrete and abstract information may be maintained in working memory (WM) via activity of different regions in the parietal and the prefrontal cortices. However, mechanisms by which concrete and abstract information are maintained in WM are still unclear. Here, we used electroencephalogram (EEG) to test the hypothesis that abstract information is represented in WM as an active pattern of neural activity that is similar to, but independent from, the activity that represents concrete information in WM. Subjects performed two types of WM task; one required the maintenance of locations of items ("item-specific"), which involved memory for a particular retinotopic location, while the other required maintenance of the relative location of items (e.g. left of, right of, "relation"), which was not associated with a specific location. Consistent with previous results, we found that alpha power in posterior electrodes was greater for electrodes ipsilateral to the cued visual field than contralateral. In addition, we found that this laterality effect was stronger in the item-specific than in the relation condition. Multivariate pattern classification revealed that, during the delay period, the degree to which the posterior electrodes represented the cued visual field was significantly lower in the relation than in the item-specific condition. Direct comparison between conditions revealed that alpha power in posterior electrodes was greater bilaterally in relation than item trials, indicating that sensory regions were suppressed during the maintenance of abstract information. Taken together, the results suggest item-specific, sensory-related, information may be maintained via suppression of regions that represent irrelevant sensory information. On the other hand, relational, or abstract, information appears to rely on disengagement of sensory regions, suggesting that abstract information is maintained in an active form involving different mechanisms than the maintenance of concrete information.

Acknowledgement: NIH grant R01 MH082957 to SC

16.404 **Ventral visual selectivity and adaptation in amnesia.** Jiye G. Kim[1](jiyekim@princeton.edu), Emma Gregory[2], Barbara Landau[2], Michael McCloskey[2], Sabine Kastner[1,3], Nicholas B. Turk-Browne[1,3]; [1]Princeton Neuroscience Institute, Princeton University, [2]Department of Cognitive Sciences, Johns Hopkins University, [3]Department of Psychology, Princeton University

Regions in the ventral visual cortex respond preferentially to particular categories of visual information, such as objects in the lateral occipital cortex (LOC), scenes in the parahippocampal place area (PPA), and faces in the fusiform face area (FFA). However, the role of the medial temporal lobe (MTL) memory system in ventral visual processing remains unknown. To address this issue, we examined the visual cortex of a densely amnesic individual. LSJ is a 62 year-old woman with severe anterograde and retrograde amnesia resulting from herpes encephalitis. High-resolution anatomical MRI revealed that more than 95% of her hippocampus was destroyed bilaterally; she also has extended damage to other MTL and anterior temporal regions, especially on the left. Although LSJ is profoundly impaired on memory tasks (e.g., Wechsler Memory Scale's General Memory index of <0.1 percentile), her basic sensory and language abilities are spared. We ran several fMRI sessions with LSJ. First, we investigated how MTL damage affects category selectivity in the ventral visual cortex. We conducted functional localizers, using a block design to present a series of stimuli including objects, faces, scenes and scrambled textures. LSJ showed intact object-selective LOC and scene-selective PPA. Face selectivity in FFA was less robust, suggesting a potential role for the MTL in FFA processing. Second, we investigated how MTL damage affects adaptation in the ventral visual cortex, given that the mechanisms underlying this effect remain unsettled. We tested for attenuated responses to blocks where an identical stimulus was repeated multiple times compared to blocks where multiple different stimuli were presented once. Reliable adaptation was found for objects and scenes in

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LOC and PPA, respectively. Together, these results demonstrate that the MTL may not be vital for category selectivity in the ventral visual cortex and that rapid adaptation effects are not mediated by this memory system.

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16.405 **Spatial Working Memory Capacity Estimates Correlate With the Structure of Frontal and Parietal Cortex** Nikos Konstantinou[1](nkonstantinou@gmail.com), Ryota Kanai[2,3]; [1]Center for Applied Neuroscience, University of Cyprus, [2]Sackler Centre for Consciousness Science, School of Psychology, University of Sussex, [3]Institute of Cognitive Neuroscience, University College London

A plethora of previous studies, including monkey electrophysiology and human neuroimaging, have suggested that frontoparietal regions are activated during spatial working memory (WM) tasks (Smith & Jonides, 1999). Here we aimed to identify correlations between grey matter volume and spatial WM capacity estimates in healthy young adults. We performed voxel-based morphometry on the structural MRI data of 48 young healthy volunteers to obtain measures of grey matter volume. Behavioral capacity estimates of spatial WM were obtained using a staircase method (3-up-1-down starting at 2 locations) that varied the number of locations in the memory set of a delayed-response WM task. Participants were presented with a memory set containing irregular shapes (1.5°×1.5°) that appeared for 100 ms each at peripheral locations arranged in a circle around fixation (3° from fixation). Participants maintained the location (and ignored the shape) of the memory set items. Following a 1 sec delay, a memory probe was presented for up to 3 sec that matched the location of one of the memory set items in 50% of the trials. Participants made a button press to indicate whether the memory probe matched any of the memory set locations. A multiple regression analysis using SPM8 was performed to identify cortical regions with a significant correlation with individuals' spatial WM capacity. We observed positive correlations between individual spatial WM capacity estimates and grey matter density in bilateral inferior parietal lobule (IPL) and right middle frontal gyrus (MFG). Our findings are consistent with previous work showing that these brain areas are consistently recruited during the maintenance of spatial information (Wager & Smith, 2003; Leung, Gore & Goldman-Rakic, 1999), further indicating that people with higher grey matter density in IPL and right MFG are able to maintain a greater amount of spatial information in WM.

16.406 **Consolidation of associative face memory during sleep is related to spatial position** Elizabeth McDevitt[1](mcdevitt@ucr.edu), Arash Afraz[2], Sara Mednick[1]; [1]Department of Psychology, University of California, Riverside, [2]McGovern Institute for Brain Research, Massachusetts Institute of Technology

We examined the role of non-rapid eye movement (NREM) and REM sleep for consolidation of associative face memory. Subjects (N=96) were trained to associate 20 pairs of bilaterally presented faces. At 9AM training, subjects were instructed to associate each pair by imagining family relationship, without mention of face position. At immediate test and again at 4PM, subjects were presented with pairs of faces (10 old and 10 new pairs) and asked whether the faces were in the same or different pairings as training. Faces were either presented in the same or opposite position as in the training phase. At 1PM, subjects took a polysomnographically recorded nap with or without REM sleep or remained awake. The change in face association memory (d') between the morning and afternoon test sessions was calculated for various sleep conditions. This value was contrasted for position-intact and position-flipped conditions to define a position-invariant face association index (d'Δ). Sleep did not improve retention of associative face pairs in general. However, one-way ANOVA found a difference in d'Δ between three sleep conditions ($F(2,93)=3.86$, $p<0.05$). Neither NREM or REM groups differed from wake, but NREM naps had greater d'Δ compared to REM naps ($p<0.01$). This suggests REM sleep is involved in consolidation of image-based learning for faces while NREM sleep is engaged in more abstract position-independent learning. Additionally, sleep spindles were associated with increased false alarm rate ($r=.38$, $p<.01$) and decreased d' ($r=-.29$, $p<.05$), suggesting that sleep spindles may reflect mechanisms associated with false visual memory formation. In summary, we demonstrate a differential effect of sleep stages on associative face memory related to coding for spatial position.

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16.407 **Neural Correlates of Visual Working Memory Capacity in the Posterior Parietal Cortex** Mitchell Riley[1](mriley@wakehealth.edu), Bryce Lambert[1], Xue-Lian Qi[1], Christos Constantinidis[1]; [1]Department of Neurobiology and Anatomy, Wake Forest School of Medicine

A number of prior studies in humans have shown that visual working memory capacity is limited to approximately 4 items, and this depends on the posterior parietal cortex. However little is known about the basis of capacity and its limitations at the single neuron level. In order to examine how the posterior parietal cortex encodes this information, we designed a task of visual working memory in a monkey model. We presented 1-5 visual stimuli at one of 14 locations arranged on a ring of 10 degree eccentricity. The stimulus display was presented on a computer screen twice, with a 1 second delay period between them. During the second presentation, the stimuli appeared at the same locations as in the first, though there was a 50% probability that one of them might change in shape. The monkey was required to determine if there was a change or not by making an eye movement to a blue or green choice target, respectively. We found that as the number of stimuli increased, performance declined. Capacity was estimated to be approximately 3 items. Capacity in the left and right hemifield were not independent of each other. We studied the neural basis of the phenomenon by recording neuronal activity in the posterior parietal cortex (areas 7a and LIP). We first mapped the neuron's receptive field and then positioned the stimulus that would change either in the receptive field or at a diametric location to it, and either surrounded by or away of the rest of the stimuli. We were thus able to determine the ability of single neuron activity to decode the identity of the stimulus that changed. Our results offer insights on the neural basis of visual working memory capacity at the level of single posterior parietal neurons.

Acknowledgement: Supported by NIH grant R01 EY16773 and the Tab Williams Endowment Fund.

16.408 **Testing Hemodynamic Predictions of a Dynamic Neural Field Model of Visual Working Memory** John Spencer[1](john-spencer@uiowa.edu), Aaron Buss[1], Vince Magnotta[2]; [1]University of Iowa, Department of Psychology, [2]University of Iowa, Department of Radiology

Efficient visually-guided behavior depends on our ability to form, retain, and compare visual representations separated in space and time. This ability relies on visual working memory (VWM). Although research has begun to shed light on the neuro-cognitive systems subserving VWM, few theories have addressed these processes in a neurally-grounded framework. Here, we describe a layered dynamic neural field (DNF) architecture that captures the cortical population dynamics that underlie VWM, including the encoding, maintenance and comparisons operations involved in change detection. We then test this model using fMRI. Recent work has shown that the BOLD response is strongly correlated with local field potentials (LFPs). An analog of LFPs can be estimated from DNF models. This estimate can be convolved with an impulse response function to yield hemodynamic predictions. Using this approach, we show that the DFN model quantitatively captures fMRI data from recent studies probing changes in the BOLD response in the intraparietal sulcus (IPS) as set size increases in change detection. We also test a novel hemodynamic prediction regarding the source of errors in change detection. The BOLD responses from different neural fields in the model revealed a complex relationship between false alarms and misses. Some fields showed larger BOLD responses for false alarms versus misses due to the increased synaptic activity associated with the failure to consolidate items in working memory as well as the incorrect detection of new features. Other fields showed larger BOLD responses on misses, resulting from robust maintenance of information which suppresses the detection of changes. Using fMRI, we identified cortical regions that mirrored these patterns. These data run counter to classic explanations of errors in change detection which assume perfect maintenance at low set sizes with errors reflecting guessing. Results show that the DNF model can effectively bridge the gap between brain and behavior.

Acknowledgement: NSF BCS-1029082

16.409 **Reconstructing delay-period spatial representations of remembered stimuli in visual, parietal and frontal cortex** Thomas Sprague[1](tsprague@ucsd.edu), Edward Ester[2], John Serences[1,2]; [1]Neuroscience Graduate Program, UC San Diego, [2]Department of Psychology, UC San Diego

Spatial working memory (WM) is thought to operate by enhancing the response of neural populations that selectively respond to the remembered stimulus location (Awh & Johnides, 2001). However, maps of visual space are widely distributed across regions of occipital, parietal and frontal cortex, and the relative contribution of each region to the maintenance of precise spatial information during WM has not been established. Here, we reconstructed 2D spatial representations of remembered spatial locations using a forward encoding and BOLD fMRI (similar to Sprague & Serences, VSS, 2012). The model was trained using independent scans during which participants viewed a spatially arrayed set of flickering checkerboards. Each WM trial began with the presentation of two small (0.23°) peripheral stimuli. After 0.5 s, a post-cue instructed subjects to remember the location of a single stimulus, the locations of both stimuli, or to simply wait for the next trial to begin (i.e., passive fixation). After an 8 s delay period, a single probe item was presented and subjects made a 2AFC response indicating whether the probe occupied precisely the same location as the matching remembered stimulus. Probe/target separations were manipulated using the method of constant stimuli, which allowed for estimation of spatial WM precision during scanning. We then reconstructed the spatial representations of the remembered locations using patterns of activation measured during the memory delay period. Robust reconstructions of remembered – but not forgotten – positions were observed in a multitude of frontal (e.g., sPCS, the human homolog of macaque FEF), parietal, and occipital (V1-V3) regions. These results suggest that spatial WM is supported by the operation of widely distributed cortical maps that extend well beyond retinotopically mapped regions of early visual cortex.

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16.410 **Cross-Talk Between Visual Short-Term Memory and Low-Level Vision: Evidence for Interactions Across Shared Neural Resources.** Nicholas M. Van Horn[1](van-horn.73@osu.edu), Alexander A. Petrov[1]; [1]Department of Psychology, Ohio State University

Visual short-term memory (VSTM) is often characterized as a temporal buffer whose content is protected from subsequent visual input. However, recent human and monkey studies suggest that VSTM shares overlapping neural resources with low-level vision and is subject to interference from visual input. The present study used tilt aftereffects to reveal the reciprocal to also be true: VSTM can augment perception, thus creating distorted perceptions relative to the ground truth. Method: For twelve observers, three Gabors – Sample, Target, & Match — were presented sequentially on each trial. In VSTM blocks, observers held the orientation of the Sample in VSTM and reproduced it later by manipulating the Match. In control blocks, the Sample was viewed for the same amount of time, but reappeared during the Match phase. The dependent variable of interest was response bias on a binary CW/CCW discrimination task involving the Target Gabor sandwiched between the Sample and Match. Unbeknownst to the subjects, the Target orientation was always exactly vertical. A concurrent attentional task forced observers to foveate the Sample. Results: The responses on the CW/CCW task were biased away (~59%) from the Sample orientation in the control condition, indicating a tilt aftereffect as expected. The new result is that the response bias was twice as strong (~68%) in the VSTM condition. Conclusion: This demonstrates that visual perception is not fully insulated from VSTM. Rather, VSTM interference can systematically alter subsequent visual processing. One potential explanation is that memory for stimulus features is subserved by connections from well-known VSTM cortical sites (e.g., prefrontal cortex) that overlap with circuits involved in the encoding of low-level stimulus features (e.g., occipital lobe). By sharing neural resources to economize representational space, the two systems are subject to cross-talk.

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16.411 **Different electrophysiological correlates underlying fragile and robust Visual Short-Term Memory.** Annelinde Vandenbroucke[1](a.r.e.vandenbroucke@uva.nl), Ilja Sligte[1], Jade de Vries[1], Johannes Fahrenfort[1], Mike X Cohen[1], Victor Lamme[1]; [1]Brain & Cognition, Psychology, University of Amsterdam

Recently, we have found evidence for a new stage of Visual Short-Term Memory (VSTM) that lies in between iconic memory and robust VSTM (Sligte et al., 2008; 2009). Classical VSTM experiments in which a Change Detection paradigm is used show that VSTM stores items in a stable form, yet it has a limited capacity of around four objects. However, when a partial-report paradigm is used, capacity can be boosted to up to twice that amount. These additional items are however erased when new objects appear, hence we term this additional storage fragile VSTM. Although behavioral evidence has been found for a dissociation between fragile and robust VSTM (Vandenbroucke et al., 2011), controversy remains whether fragile VSTM taps into a different stage of memory or whether in both fragile and robust VSTM, the same mechanism are at play (Makovksi, 2012, Matsukura & Hollingworth, 2011). In this study, we investigated whether fragile and robust VSTM have different electrophysiological underpinnings using EEG time-frequency analyses. Twenty-four subjects performed a Change Detection task in which a cue was presented in between the memory and test display (gauging fragile VSTM) or during the test display (gauging robust VSTM). Memory displays contained 2, 4, 6 or 8 oriented rectangles. For robust VSTM, ceiling performance was reached at 4 objects, while fragile VSTM performance kept rising up to 8 objects. The capacity scores for fragile VSTM and robust VSTM correlated with different frequency bands before onset of the cue, such as a relative decrease in parietal-occipital alpha activity and increase in central-parietal gamma activity for fragile VSTM. This suggests that the neural mechanisms supporting fragile and robust VSTM differ.

16.412 **Energy expended in encoding and retrieval in a visual memory task: Interactive effects of workload and body iron status** Michael Wenger[1,2](michael.j.wenger@ou.edu), Laura Murray-Kolb[3], Jere Haas[2]; [1]Psychology, Cellular and Behavioral Neurobiology, The University of Oklahoma, [2]Division of Nutritional Sciences, Cornell University, [3]Nutritional Sciences, The Pennsylvania State University

Iron deficiency (ID), with and without anemia, has been shown to have deleterious effects on physical performance. Animal models have demonstrated that physical endurance and the concentrations of oxidative enzymes and respiratory proteins all decrease in ID, even at levels that do not reach the point of anemia. Human studies have documented reductions in endurance in ID without anemia, with effects being seen in measures of energy expenditure and work efficiency. The present effort extends the examination of the effect of ID to consideration of its effects on energy use in the performance of perceptual and cognitive work in the context of a visual memory task. ID women (ferritin <16 g/dl, n = 20) and age-, education- and activity-level-matched controls (n = 17) provided blood samples for measures of iron status; completed a set of questionnaires probing general health and activity levels, menstrual status, and consumption of iron-rich foods; completed a working memory task (as a general measure of cognitive efficiency); and performed a visual Sternberg task with a concurrent mental math task. While performing the visual Sternberg task, participants' brain and metabolic states were measured using electroencephelography (EEG) and measures of the volume of O2 and CO2 in expired air, respiratory rate, and heart rate. We consider here effects of variations in workload during both encoding and retrieval. We show statistically significant relationships among behavioral, EEG, and metabolic measures, all as a function of variations in task difficulty and iron status, with lower iron status being associated with lower levels of behavioral performance and diminished potential for beginning and sustaining work. The data suggest the potential for using EEG for indirect estimation of the effects of ID on brain energy expenditure.

Acknowledgement: National Institutes of Health, National Institute of Environmental Health Sciences

16.413 **Oscillatory correlates of uploading long-term memory into visual working memory** Keisuke Fukuda[1](keisuke.fukuda@vanderbilt.edu), Geoffrey F. Woodman[1]; [1]Department of Psychology, Vanderbilt Vision Research Center, Vanderbilt University

Our visual working memory (VWM) allows us to represent a limited amount of information in a readily accessible state. To study how information is represented in VWM, studies thus far have almost exclusively examined situations in which visual stimuli are presented and maintained over brief retention intervals. These studies have successfully identified neural correlates of VWM representations. For instance, event-related potential (ERP) studies showed that the sustained negativity observed over parieto-occipital channels increases as the function of a set size up to individuals' VWM capacity, plateauing at larger set sizes (e.g. Vogel & Machizawa 2004). Recently, we also found that alpha band power measured at the same time over the same channels shows the same set size function (Fukuda & Vogel 2011). However, it is still unclear how information retrieved from visual long-term memory (VLTM) is represented in VWM. In this study, we first had participants learn spatial layouts of colored objects that varied in their set size (i.e., 1 2 4 or 8 objects). When learning was complete, participants were instructed to retrieve learned arrays while we recorded their scalp EEG activity to examine previously established neural correlates of VWM. Here, we found that while the ERPs did not differentiate the set size of the learned arrays participants retrieved, the oscillatory activity did dissociate the set size of the arrays by mirroring the pattern observed when VWM is used to store information that was just presented in the visual field. That is, when participants were accessing the learned arrays, the alpha band power showed a monotonic decline up to the set size 4 with no further decreases for large arrays. These findings not only dissociate the ERP and oscillatory correlates of VWM, but also provide insights as to how VWM supports a diversity of operations during visual cognition.

Acknowledgement: NEI (RO1-EY019882), NSF (BCS 09-57072)

16.414 The contralateral delay activity is insensitive to microsaccades induced by increasing number of items in visual working memory Min-Suk Kang[1,2], Geoffrey Woodman[2]; [1]Department of Psychology, Sungkyunkwan University., [2]Department of Psychology, Vanderbilt University

The Contralateral Delayed Activity (CDA) has been a powerful tool with which to measure the representation of items in visual working memory. However, there are two reasons to believe that the CDA might reflect miniature gaze-shifts instead of working memory representations. First, to measure the CDA, subjects are presented with bilateral memory arrays but are asked to remember only items in one visual hemifield. This could elicit eye movements in the direction of the remembered items. Second, recent studies have shown that microsaccades modulate the occipitoparietal EEG and ERP responses (Yuval-Greenberg et al., 2008; Dimigen et al., 2009). To test the hypothesis that systematic microsaccades underlie the CDA, we recorded subjects' EEG and averaged ERPs during change-detection tasks while also using high-resolution eye tracking (EyeLink 1000). Despite strict instructions to maintain fixation and the use of a stringent criterion for rejecting artifacts associated with eye movements, we found that the averaged gaze position was systematically shifted toward the hemifield of the memoranda during the retention interval. Moreover, the magnitude of these shifts increased with memory set size. However, we found that the CDA amplitude was insensitive to the magnitude of the gaze shifts within a given set size. We found an important dissociation between eye position measured with the video-based eye tracker and the horizontal electrooculogram (HEOG). The findings indicate that the HEOG picks up some of the neural activity underlying the CDA and the maintenance of representations in visual working memory. The findings demonstrate practical limitations in the use of HEOG to measure eye movements during ERP and EEG studies of visual memory. Additional implications of these results will be discussed in the context of the locus of the neural representations of working memory.

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16.415 Interhemispheric synchrony in occipital cortex predicts mnemonic precision in working memory David E. Anderson[1](dendersn@gmail.com), Edward K. Vogel[1], Edward Awh[1]; [1]Department of Psychology, University of Oregon

Working memory (WM) stores detailed representations in an online state by recruiting the same cortical regions that encoded those items (e.g., Serences et al., 2009; Harrison & Tong, 2009). More recently, we found that mnemonic precision is correlated with the dispersion of orientation-specific population responses in primary visual cortex, indicating that these population codes play a functional role in supporting the fidelity of WM representations. In the current work, we investigated the mechanism by which these population responses are knit together across distinct regions of visual cortex. One prominent hypothesis is that activity across disparate neural units is bound together by virtue of temporal synchronization (Fries, 2005; Fell & Axmacher, 2011). Here, we corroborate this hypothesis with evidence that the degree of phase synchronization across brain regions strongly predicts individual differences in mnemonic precision. Observers stored a single foveally presented orientation in visual working memory while we measured EEG. Neural synchrony was measured by examining the degree to which the phase of ongoing oscillatory activity was matched across an electrode pair. The key finding was that phase synchronization (in the upper alpha to lower beta bands, 10-15 Hz) was strongly predictive of which observers had the most precise recall of the stored orientation; this was observed across both occipital ($R2=.3$) and parietal ($R2=.33$) electrode pairs. Finally, we collected the same measures using a lateralized stimulus and found that (1) The phase of oscillatory activity measured in the ipsilateral electrode lagged behind that in the contralateral electrode until 200 ms after the onset of the stimulus, and (2) The relationship between WM precision and phase synchrony was observed only after interhemispheric synchrony was established. Together, these studies support the hypothesis that the precision of visual WM representations is determined by the sustained global synchronization of feature-selective population codes.

16.416 Hemispheric remapping in VWM across changes in attention and eye position Brittany J. Dungan[1](bdungan@uoregon.edu), Atsushi Kikumoto[1], Edward K. Vogel[1]; [1]Department of Psychology, University of Oregon

We perceive a stable world despite frequent shifts in eye position and attentional focus. These shifts often cause objects to be translated from one visual field to another. However, it is unclear how such translational shifts in eye position or attention affect which cerebral hemisphere will represent objects of interest. Are the items immediately remapped to the new hemisphere following the shift, or do they continue to linger in the initial encoding hemisphere? Here, we examined hemispheric remapping following either a change in eye position or attentional focus. We recorded a sustained working memory component (Contralateral Delay Activity; CDA) of the event related potential while subjects performed a change detection task in which the items remained continuously visible. Subjects began all trials by fixating a central cross prior to the presentation of the memory array. In the eye movement block, subjects either maintained central fixation throughout the entire trial, or they were cued to refixate a new position that was 7 degrees to the left or right of central fixation during the middle of the retention period (bringing the objects into a new visual field). In the attention movement block, subjects maintained central fixation and either attended to an initially cued set of items in one hemifield throughout the entire trial, or were cued to shift their attention to the items in the opposite visual hemifield during the middle of the retention period. The results from the eye movement condition showed a sustained CDA that persisted in the original contralateral hemisphere even after the subjects had refixated. By contrast, when subjects shifted attention to the items in a new visual field, the CDA rapidly flipped in polarity, indicating that the item representations had been remapped to the other hemisphere.

16.417 Decoding trial by trial variations in VWM performance from oscillatory activity during maintenance. Irida Mance[1](iridam@uoregon.edu), Keisuke Fukuda[2], Edward Vogel[1]; [1]Department of Psychology, University of Oregon, [2]Department of Psychological Sciences, Vanderbilt University

Visual short term memory (VSTM) allows us to maintain a handful of representations in a highly accessible state. While this capacity limited system is well known to vary systematically between individuals, the within-individual variability of memory capacity is not well characterized. This stems from the prevalent use of partial report tasks such as change detection and cued recall tasks, in which only a single item from an array is probed. These procedures make it challenging to quantify the amount of information available in memory from individual trials. Here we examined within-subject variability using a whole report task, in which subjects reported the color and orientation of each item of the array after a memory delay. Our behavioral results indicated that while the modal number of items correctly recalled was three items, there was a substantial proportion of trials in which subjects recalled fewer or greater than this mode. We also recorded EEG from subjects during the task to examine whether the observed within-subject variability in performance reflected trial-by-trial variation in neural activity during the maintenance period. Time-frequency analyses of the EEG indicated that average power in the 8-22 Hz band during maintenance decreased as a function of the number of items in the array, reaching an asymptote at approximately 3 items. We used a linear classifier on the bandpassed individual trial EEG during the retention period and found that it could reliably distinguish the upcoming behavioral outcome on that trial (1,2 or 3 correct out of 6 items). Our results suggest that memory capacity is not fixed across trials and that this trial-by-trial variability is driven in part by variations in the sustained 8-22hz desynchronization during memory maintenance.

16.418 Gradual decay and death by natural causes in visual working memory. Daryl Fougnie[1](darylfougnie@gmail.com), Jordan W. Suchow[1], George A. Alvarez[1]; [1]Vision Lab, Psychology Department, Harvard University

Working memory performance declines when items are stored over long intervals, suggesting that memories degrade over time. Here we examine the nature of this information loss from working memory. One possibility is that items gradually fade in quality, becoming less veridical over time. Alternatively, items may drop out of memory suddenly (termed sudden death). Recently, Zhang & Luck (2009) claimed to have found evidence for sudden death by showing that, over time, the number of remembered items decreases while the quality of those that remain is roughly constant. We considered an alternative model in which information is lost gradually over time, leading to failure once information about an item is depleted ("death by natural causes"). The inspiration for this model is the finding that working memories are variably precise (Fougnie, et al., 2012, van den Berg et al., 2012) and the possibility that poorly-remembered items are more likely to fail or are harder to retrieve. Our model draws on signal detection models where items are coded by independent samples that are averaged to reduce uncertainty. We propose that time-based changes in memory occur from volatility in stored information—samples are lost independently of each other over time, resulting in representations that gradually decay until they cease to exist. The moment a poorly-remembered item is forgotten, its removal improves the average quality of the remaining items, masking gradual decay and producing results that have been taken as evidence of sudden death. This model performed better than the sudden death model at describing changes in memory quantity, quality, and variability over time. Furthermore, the model can be

fit at one time point and predict data at other time points by adjusting only the expected number of lost samples. Thus, we find that memories do not suddenly fail, but slowly degrade until death by natural causes.
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16.419 **Evolutionary dynamics of visual memory** Jordan W. Suchow[1](suchow@fas.harvard.edu), Benjamin Allen[2,3], Martin A. Nowak[3], George A. Alvarez[1]; [1]Department of Psychology, Harvard University, [2]Department of Mathematics, Emmanuel College, [3]Program for Evolutionary Dynamics, Harvard University

Visual memory enables a viewer to hold in mind the details of objects, textures, faces, and scenes. After initial exposure to an image, however, visual memories rapidly degrade because they are transferred from iconic memory, a high-capacity sensory buffer, to working memory, a low-capacity maintenance system whose flexibility affords a workspace for thought. Here, we extend the classic depiction of the dynamics of visual memory to account for competitive interactions between memories, fluid reallocation of mental resources, and mutual interference. The proposed model is equivalent to a generalization of the Moran process of evolution in finite populations. When applied to the mental commodity that provides a substrate for memories, the process helps to explain the time course of the capacity, quality, variability, and reliability of visual memory. The process also provides an explanation for why, in the absence of distraction or misattribution, the limiting behavior of visual memory is neither full retention nor complete loss, but the stability of a lone memory, having reached fixation in the mind. Structured substrates, e.g. gridded visuotopic maps like those found in visual areas in the brain, are shown to preserve memories better than substrates without explicit structure. Evolutionary models provide quantitative insights into the mechanisms of memory maintenance.

Development: Atypical aging and development

Friday, May 10, 5:30 - 8:00 pm

Poster Session, Orchid Ballroom

16.420 **Cortical visual processing in patients with congenital achromatopsia: coherent form, motion and biological motion perception** Eliza Burton[1](eliza.burton@ucl.ac.uk), John Wattam-Bell[1], Koji Nishiguchi[1,2], Venki Sundaram[1,2], Jonathan Aboshiha[1,2], Andrew Webster[1,2], Anthony Moore[1,2], Michel Michaelides[1,2], Marko Nardini[1]; [1]University College London, [2]Moorfields Eye Hospital

Congenital achromatopsia is characterised by an absence of functioning cone photoreceptors, resulting in poor visual acuity and no colour vision. While previous psychophysical studies have investigated basic functions including acuity and contrast sensitivity, little is known about the effects of achromatopsia on mid- and higher-level vision. We measured coherence thresholds for form, motion and biological motion in four patients and six controls under varying light levels, including scotopic conditions in which controls and patients were comparable in being reliant only on rods. The patient group showed higher coherence thresholds at all light levels for the form and motion tests, while their biological motion thresholds were comparable to controls. Additional tests confirmed that poor contrast sensitivity could not account for these results in three out of four of the patients. The second phase of the study will use vERPs to measure and localise cortical responses to these stimuli. Previous research with controls has shown distinct patterns of activation in response to coherent form and motion, namely a midline response to motion and a lateralised response to form [Wattam-Bell et al, 2010, Current Biology, 20, 411-415]. Data we have collected with controls has also demonstrated a specific right hemisphere response to biological motion. These results will be compared to those from patients in order to determine the extent to which elevated form and motion thresholds reflect atypical patterns of cortical processing. Our results show that visual impairment in congenital achromatopsia extends beyond previously examined low-level visual functions, to include coherent form and motion perception. This suggests that atypical photoreceptor function can affect the development of cortical visual processing. Potential advances in treatments for genetic visual disorders including retinal gene replacement therapy raise questions regarding neural plasticity, including the extent to which cortical visual processing can be reorganised following restoration of photoreceptor function.

16.421 **Global motion coherence performance after extended congenital blindness: stretching the window** Garga Chatterjee[1](garga@fas.harvard.edu), Amy Kalia[1], Tapan Gandhi[1], Pawan Sinha[1]; [1]Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology

Global motion perception is an important building block of visual development. Here we focus on the development of this ability itself. Specifically, we explore the impact of early visual deprivation on the availability and development of this ability. This issue has both basic and applied implications related to sensitive periods in visual development and prognoses for sight-restoring surgeries late in childhood. Examples of global motion assessment after recovery from extended blindness are scanty (Ellemberg et al., 2002; Fine et al., 2003). As a part of Project Prakash, we studied 8 subjects who were blind for the first 8 to 17 years of life because of very-early onset bilateral cataracts. Global motion perception was assessed by measuring coherence thresholds using random dot kinetograms (Newsome and Paré, 1988). The assessments were conducted 4 months to 2 years post cataract removal. All subjects had above chance global motion coherence thresholds with the performance of some subjects approaching near-normal levels. Evidence for even partial acquisition of global motion coherence is significant in that it shows that even extended periods of blindness starting near birth do not entirely preclude the development of this ability. The present data greatly extends the window of very early onset blindness duration after which acquisition or development of global motion coherence sensitivity is possible.
Acknowledgement: NIH R01EY020517

16.422 **Emergence of face-localization abilities following extended congenital blindness** Tapan Gandhi[1](tgandhi@mit.edu), Amy Kalia[1], Garga Chatterjee[1], Pawan Sinha[1]; [1]Brain and Cognitive Sciences, MIT

The human visual system is remarkably adept at localizing faces in complex natural scenes. It is unclear whether this skill has innate roots or is acquired through visual experience. Operational challenges involved in working with newborn infants make this a difficult issue to address definitively. Here we explore this question in the context of late sight onset. Project Prakash has provided us with an opportunity to work with individuals deprived of pattern vision since birth. We tested face localization skills of ten newly sighted children, ranging in age from 8 to 23 years. Subjects were presented with three versions of the face-localization task in complex natural scenes. The three conditions corresponded to 1. Faces shown with bodies, 2. Full heads, and 3. Only the internal facial features. We found that the newly-sighted children showed poor face localization immediately after sight onset, favoring an empirical, rather than nativist, account of skill acquisition. Furthermore, longitudinal assessment of performance showed that bodies and external head contours were important cues over the early course of this developmental trajectory. These results suggest that plasticity for face learning is preserved even late in childhood. Furthermore, the pattern of performance observed across the three different stimulus conditions has implications for understanding the mechanisms that subserve face-learning soon after sight onset.
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16.423 **Hemispheric differences in the human lateral geniculate nucleus** Monica G. Chica[1,2](phd@monicagiraldochica.com), Keith A. Schneider[2,3]; [1]Department of Medicine, University of Barcelona – Spain , [2]Centre for Vision Research, York University – Canada, [3]Department of Biology, York University – Canada

Introduction: Human brain asymmetry has been observed in previous studies and been related to a normal specialization of functional roles. Greater asymmetry between hemispheres has been associated with increased capabilities, such as enhanced processing auditory features, while smaller asymmetry has been linked to decreased capabilities, like dyslexia. Here we investigate hemispheric differences in the human lateral geniculate nucleus (LGN), a visual relay and control nucleus in the thalamus. Methods: 26 subjects (13 controls and 13 subjects with dyslexia) were scanned with a Siemens Trio 3T MRI scanner. For each subject, 40 proton density weighted images were acquired with a resolution of 0.75 ´ 0.75 ´ 1 mm3. The LGN were traced manually on these images by six independent observers. The median masks of right and left LGN of all subjects from each population were registered according to their centers of mass and averaged to create four probability maps. The left maps were then reflected for comparison with the right ones. Finally, we determined the principal axis of orientation of the LGN by fitting a plane through it that minimized the perpendicular distance from each point of the LGN to the plane. We then obtained the

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inclination angle of this plane in the subjects' native spaces and compared the orientations between hemispheres. Results: The difference in probability maps revealed morphological differences between the left and right LGN. The orientations of the LGN in the two hemispheres differed by 23.9 ± 5.4° (mean ± SEM), which was highly significant (p = .003). The right LGN was oriented more vertically in the coronal plane and the left more horizontally. There were no significant differences between dyslexics and controls. Conclusions: We have observed previously unreported asymmetries in the morphology and orientation of the human LGN between hemispheres. The functional implications of these differences are unknown.

Acknowledgement: Dana Foundation

16.424 **Impaired Ability to Infer Intentionality in Children Born at Very Low Birth Weight** Kathryn Williamson[1](umwill37@cc.umanitoba.ca), Lorna Jakobson[1]; [1]Clinical Psychology, University of Manitoba

Children born at very low birth weight (VLBW; <1500 g) are at increased risk for impairments affecting social functioning, including autism spectrum disorders (Johnson et al, 2010). One area that has not been examined in this population is theory of mind (ToM) reasoning: the ability to attribute mental states (beliefs, intentions or desires) to oneself and to others. In the present study we used the Happe-Frith Animated Triangles task to study this ability in VLBW children and full-term controls. Participants included 34 VLBW children and 36 full-term controls, aged 8-11 years. Groups were comparable in terms of age-at-test, processing speed, verbal IQ, gender, handedness, and SES. They completed the Animated Triangles task, which includes animations depicting two triangles moving randomly with respect to one another (random), ones depicting physical interactions (goal-directed), and ones depicting interactions with implied intentionality (ToM). As descriptions provided by VLBW children were shorter than those of full-term peers [t(68) = 2.4, p<.02] we controlled for description length (word count) in subsequent analyses. Although the groups did not differ in terms of the degree of certainty they displayed when describing the animations, VLBW children generally provided less appropriate descriptions than their peers [F(1,67)=4.0, p<.05]. However, both groups of children found it most challenging to describe the ToM displays appropriately [F(2,134) = 5.8, p<.005]. Importantly, VLBW children over-attributed intentionality to shapes in the random displays and under-attributed intentionality those in the ToM displays; performance with the goal-directed displays did not differ between the groups [F(2,134)=9.5, p<.001]. Together, these results suggest that, like adults with autism (e.g., Castelli et al 2002), VLBW children are impaired in their ability to use dynamic cues to attribute intentionality. This impairment may reflect atypical development of and/or functioning in the superior temporal sulcus – a region implicated in this ability (Castelli et al. 2002).

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16.425 **Visual Motion Processing Deficits in Alzheimer's Disease Patients can be Modeled by Delayed Feedback** N. Andrew Browning[1](buk@bu.edu); [1]Center for Computational Neuroscience and Neural Technology, Boston University, MA

Alzheimer's disease patients (AD) have reduced ability to perceive behaviorally-relevant visual information. Verlarde et al. (Journal Alzheimer's Disease, 2012) found that AD patients required a higher signal to noise ratio for perception of heading compared to controls. It is likely that this contributes to some of the navigational deficits observed in AD patients. If you cannot tell where you are going, it is hard to get to your destination. AD patients suffer from late-stage myelin breakdown as a precursor to plaque build-up, resulting in slower conduction of signals within the brain. This work explains heading perception deficits in terms of the conduction of signals within and around heading selective brain area MST. We model MST with a variant of the ViSTARS model (Browning et al. Cognitive Psychology, 2009) of primate heading perception: motion vectors in model area V1 feed into model area MT which pools over space and time to resolve the aperture problem, MT then feeds in to model MST where heading is perceived. Lateral feedback within MST forms part of the neural circuit for discriminating heading, and feedback from MST to MT helps MT resolve noise in the optic flow estimates. Perceived heading direction is represented as a peak in the population activity in MST, the sharper the peak the more confidence the circuit has in the direction of heading. Our experiments show that feed-forward behavior of the network is slowed by reduced conduction speeds but does not result in differences in noise tolerance. In the absence of noise, feedback is largely irrelevant. However, as noise in the global motion estimate increases, feedback becomes increasingly important for high confidence discrimination of heading. In high noise environments with slow feedback, the neural circuit becomes confused, indicating that delayed feedback signals may be a significant contributor to AD visual-motion impairments.

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16.426 **The effects of Multi-Layer Release Methylphenidate on drivers with Attention-Deficit/Hyperactivity Disorder as a function of driver age** Lana Trick[1](ltrick@uoguelph.ca), Ryan Toxopeus[1], Umesh Jain[2], Kim Saliba[3]; [1]Dept. of Psychology, University of Guelph , [2]Centre for Addiction and Mental Health, Division of Child, Youth, and Family, University of Toronto, [3]Dept. of Human Development and Applied Psychology, Ontario Institute for Studies in Education/University of Toronto

Individuals with Attention-Deficit/Hyperactivity Disorder (ADHD) are at disproportionate risk of collision when driving. Recently efforts have been made to determine whether stimulant medications improve driving in individuals with ADHD. This study was designed to measure the effects of long-acting Multi-Layer Release (MLR) Methylphenidate using a double-blind placebo-control crossover design. A fixed-base driving simulator was used to measure driving performance (a full car body surrounded by viewing screens providing a 300o wrap- around virtual reality). Drivers with a history of ADHD and meeting the DSM-IV criteria for ADHD were recruited. Methylphenidate dosage was optimized and stabilized before testing began (M dosage = 47.7 mg). Thirty drivers between the ages of 21 and 65 years were tested in the simulator on two weekends, one week with their usual dose of MLR Methylphenidate and the other with a placebo. (Half the drivers began with the medication; the other half began with the placebo.) Each test day drivers were tested 1hour before the treatment/ placebo and then 2, 9, 12, 14 and 16 hours post-administration. Driving performance was measured in terms of collisions, hazard response time, steering variability, and driving speed. The age range of drivers in this study was larger than in previous ADHD studies and age appears to have an influence on the effect of the treatment on driving. Post-hoc analyses revealed that although the medication significantly improved performance in drivers under the age of 45, as shown in hazard response times and time spent speeding, there was no corresponding improvement in drivers over the age of 45. This may mean that older drivers with ADHD learn strategies to compensate for their deficits and consequently no medication-effects were observed. Alternatively, this may mean that there are age differences in the effects of medications such as MLR Methylphenidate on driving performance.

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Spatial vision: Neural mechanisms

Friday, May 10, 5:30 - 8:00 pm

Poster Session, Orchid Ballroom

16.427 **Precursors of orientation processing in the human LGN** Sam Ling[1](s.ling@vanderbilt.edu), Michael Pratte[1], Frank Tong[1]; [1]Vanderbilt Vision Research Department, Vanderbilt University

The lateral geniculate nucleus (LGN) is the first site in the brain to receive incoming signals from the retina, and is potentially well situated for early processing and active filtering of sensory information. Although most models of vision assume that orientation processing emerges in the primary visual cortex (V1), neurophysiological evidence suggests that predicates of orientation selectivity occur at earlier stages of processing – within the LGN and even the retina. Here, we used functional MRI in combination with multivariate pattern analysis to examine whether orientation selectivity, a visual feature commonly associated with visuocortical processing, exists in a more rudimentary form within the human LGN. We measured BOLD activity while participants viewed either oriented logarithmic spiral gratings at ±45° pitch, or linear gratings oriented ±45°. To ensure that fMRI decoding of the viewed orientation relied on orientation-selective information, rather than retinotopic luminance differences, the spatial phase of the grating was randomly determined on each presentation within each block. Our results revealed that reliable orientation information can be extracted from the activity patterns in the LGN, both for the spiral and linear gratings. Although modest in comparison to V1, orientation decoding in the LGN was statistically significant in all individual observers. These results suggest that orientation information may be processed to some extent before visual signals have entered the cortex, presenting an important variable to consider in models of orientation processing.

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16.428 **Neural population dynamics change perceived orientation**

Maria del Mar Quiroga[1](mar@vision.rutgers.edu), Adam Morris[1], Bart Krekelberg[1]; [1]Center for Molecular and Behavioral Neuroscience, Rutgers, the State University of New Jersey

Recurrent connections are known to play a role in the coding of orientation in primary visual cortex (e.g. for contrast invariance) but many questions remain regarding their precise functional role and possible byproducts. Previously, we implemented a recurrent model of orientation selectivity and tested responses to pairs of gratings presented briefly in succession (adapter and test). The model generated repulsive shifts in tuning curves that matched those found experimentally in V1. Unlike the shifts produced with long adaptation periods (thought to underlie the tilt after-effect [TAE]), which are well accounted for by plasticity, the repulsive shifts we observed were the result of slow population dynamics only. These effects on tuning curves gave rise to attractive shifts in the population response towards the adapter, suggesting that perception of the test orientation should -under such conditions- be biased towards the adapted orientation. Methods: To test this prediction, we asked human subjects to determine which of two Gabors (test and reference) presented simultaneously for a short period of time (≤100 ms) at either side of the fixation dot was tilted more clockwise. Crucially, the test was preceded by another oriented Gabor (adapter) in the same location (≤100 ms), while the reference was preceded by a non-oriented pattern matched for contrast and spatial frequency. Both test and reference were succeeded by non-oriented patterns to reduce afterimages. Results: The psychometric curves exhibited significant shifts consistent with an attraction of perceived orientation of the test towards the adapter. The observed effect matches the predicted effect of population dynamics, and is opposite in direction to the more commonly studied TAE. Conclusion: Population dynamics affect the coding of information and behavioral responses at fast timescales and can produce adaptation-like effects even without any form of neural plasticity.

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16.429 **Orientation-specific surround suppression is not alleviated by voluntary attention**

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The perception of a stimulus is modulated by the spatial interactions in the visual field as well as by the behavioral goals of the perceiver. We examined the interaction between two kinds of modulation of contrast perception: the allocation of voluntary visual spatial attention and stimulus-driven orientation-specific surround suppression (OSSS). OSSS is the reduction in the perceived contrast of a target that occurs when a collinear grating is placed adjacent to the target. In non-human primates, attention has been shown to relieve surround suppression in neuronal firing rates. We asked whether allocation of voluntary attention would counter the perceptual effects of OSSS. We tested 16 observers in a two-interval forced-choice task. In each trial, participants viewed two gratings, each embedded in a surround annulus on opposite sides of the fixation, followed by a single isolated grating in one location and were instructed to indicate which of the intervals contained the higher contrast at that location. At the beginning of each trial, one location was cued and the judgment was more likely to be performed at that location (70% valid). The point of subjective equality (PSE) was determined for valid/invalid/neutral cue trials and for collinear/orthogonal surround conditions. Replicating previous results, we found that OSSS reduced the perceived contrast of the embedded grating when a collinear surround grating was present, relative to an orthogonal surround ($F1,14=27.5$, $p<0.05$). We found that allocation of voluntary attention did not affect the PSE ($F1,14=0.18$, $p=0.68$). The slope of the psychometric curve was significantly shallower in the invalid cue cases ($F1,14=6.0$, $p<0.05$) and also for the collinear, relative to the orthogonal, surround condition ($F1,14=7.6$, $p<0.05$). Taken together, these results suggest that while OSSS affects both perceived contrast and sensitivity, voluntary attention only affects sensitivity. In addition, attention does not seem to relieve the perceptual effects of OSSS.

16.430 **Optimal stimulation for population receptive field mapping in human fMRI**

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Introduction: Population receptive field (pRF) mapping is a model-based approach to estimating the visual field position tuning of neuronal populations. While pRF methods are better predictors of visual field maps than conventional phase-encoded methods (Dumoulin & Wandell, 2008; Zuiderbann et al., 2012), the optimal stimulation paradigm for producing visual field maps and effective pRF size estimation remains unclear. Method Visual stimuli: dynamic, high-contrast stimulus within bars in either 1) linear or 2) logarithmic configurations (bar width scaled with eccentricity) drifting along cardinal and oblique directions. Each aperture comprised 560 volumes. A 'ridge' stimulus consisting of frequency-dissociated wedge and ring sections of the stimulus was also presented for 280 volumes. Scan parameters: Three neurotypical adults underwent fMRI at 3T (TR= 2.55, voxel= 2.3x2.3x2.3 mm3). Data analysis: pRF predictions with a simple Gaussian model were convolved with an independently-estimated hemodynamic response function and compared to the observed fMRI responses at every surface point for each condition. Results 1. We observed no difference in visual region delineation between conditions; regions V1-V7, and VO, LO and MT complexes were identified in all subjects. 2. While the linear and logarithmic conditions produced similar results, the ridge condition produced significantly better model fits than other conditions. 3. Linear bars produced significantly higher pRF size estimates ($\sigma = 4.81, \pm 1.93$) than either its logarithmic counterpart ($\sigma = 3.41, \pm 1.63$, $p<.05$) or the ridge stimulus ($\sigma = 3.41 \pm 1.01$, $p<.01$). Discussion These results highlight that pRF parameter estimation is constrained by the stimulus configuration used. Linear bars produced larger sigma estimates and poorer model fits compared with methods that account for cortical magnification. Finally, ridge stimulation allows reliable parameter estimation and accurate model fitting within a much shorter scanning time, half of the time required for bar stimulation.

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16.431 **Collinear facilitation by invisible flankers**

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The detectability of a Gabor patch (target) at the fovea is improved by two high contrast, aligned, flanking Gabor patches (flankers). This effect is termed collinear facilitation (Polat & Sagi, 1993). Hayashi & Murakami (VSS2012) tested collinear facilitation with a vertically oriented pattern as a target and concentric Laplacians shown above and below as flankers, demonstrating that such flankers with no predominant orientation can also facilitate the target detection. However, the amount of facilitation was smaller than that obtained using conventional oriented flankers, suggesting the visibility of flanker orientation playing some role. In the present study, we further examined the influence of the flankers' visibility by making use of a method called continuous flash suppression (CFS) (Tsuchiya & Koch, 2005). The target was a vertical D2 pattern, and two flankers were presented above and below the target. All of them were presented monocularly. We measured the detection threshold of the target by two-interval forced choice. Three flanker types were tested: a vertical pattern, a horizontal pattern, and an isotropic concentric Laplacian. These flankers were made invisible by CFS due to dynamic maskers presented to the other eye throughout the experiment. The vertical flankers still caused significant facilitation whereas the horizontal flankers and the Laplacian flankers did not. These results indicate two things. First, facilitation with vertical flankers does not require the awareness of the flankers, which means that the collinearity that is necessary for facilitation is only a neural one established by lateral interactions of orientation-selective units in an early, unconscious stage of visual processing. Second, facilitation with isotropic Laplacian flankers requires the awareness of the flankers, which means that the mechanism of this facilitation is different from that of conventional collinear facilitation and the responsible stage for this facilitation may be located in a higher stage of visual processing.

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16.432 **Oriented luminance gratings, but not noise patterns, induce narrow gamma band ECoG responses in human visual cortex**

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Purpose: A prominent feature of many recordings of stimulus induced field potentials in visual cortex is a narrowband increase in power centered within the gamma band (30-100 Hz). The narrowband peak has attracted a great deal of attention, with suggestions that it may reflect neural activity critical for fundamental perceptual and cognitive processes. However, recent studies of local field potentials in cat and macaque have shown that the characteristics and even presence of the induced narrowband response depend on the image spatial structure, indicating that this response may not be essential for seeing. We tested whether stimulus-induced narrowband gamma responses can be measured in human visual cortex using electrocorticography (ECoG), and whether the presence of these responses is dependent on the image spatial structure. Methods: A clinical subject with subdural patch electrodes (2.3 mm diameter) was presented with static images for 500 ms each (1000 ms ISI). Seven classes of stimuli were presented (30 exemplars per class), including high contrast vertical gratings (0.16, 0.33, 0.65, or 1.3 cpd square wave) and noise patterns (1/f^4, 1/f^2, and 1/f^0 spectral power distributions). Results: ECoG responses to the images were measured in 11 electrodes adjacent to V1 or on the V1/V2 boundary. The temporal ECoG response could be separated into (1) a broadband spectral increase of up to 200% above baseline, spanning frequencies from <20 Hz to >150 Hz, and (2) a gamma band increase of up to 1500% above baseline, peaked between 30 and 50 Hz. The noise patterns only elicited the broadband response, whereas the grating stimuli elicited both the broadband and the narrowband gamma responses. Conclusions: Narrowband gamma responses can be induced in human visual cortex and reliably measured with ECoG. These responses arise in response to certain types of visible image patterns, but not in response to all images.

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16.433 **Examining the Laminar Profile of Surround Suppression in V1 using High Resolution fMRI at 7 Tesla** Michael-Paul Schallmo[1](schal110@umn.edu), Cheng Qiu[2], Essa Yacoub[3], Cheryl Olman[2]; [1]Graduate Program in Neuroscience, University of Minnesota, [2]Department of Psychology, University of Minnesota, [3]Department of Radiology, University of Minnesota

Surround suppression is an early visual cortical phenomenon believed to play an important role in processes such as figure-ground segmentation. This suppression from outside the classical receptive field is tuned to the relative orientation of center and surround stimuli; we refer to this specifically as orientation-dependent surround suppression (ODSS). Despite extensive investigation, the neural mechanisms of ODSS in early visual cortex are not well understood. Recent investigations using very high resolution spin-echo weighted fMRI have demonstrated that the laminar profile of the V1 BOLD signal is differentially sensitive to the configuration of visual stimuli. Due to the distinct patterns of local and long-range projections which exist at different cortical depths, the ability to examine the laminar profile of neural activity and its relationship to visual behavior can provide insight into the mechanisms of early visual processing. We investigated cortical depth-dependent profiles of BOLD activity in V1 during ODSS using high resolution fMRI at 7 Tesla. Data were acquired using both gradient echo (GE, 1 mm isotropic resolution) and 3D GRASE (GRadient And Spin-Echo, 0.8 mm isotropic resolution) sequences. V1 regions of interest (ROIs) representing center stimuli were defined retinotopically. Perceived contrast of center stimuli was lower with parallel than with orthogonal surrounds, as expected. Overall (throughout the cortical depth, both pulse sequences, all subjects), BOLD responses in V1 regions representing center stimuli were suppressed for parallel compared with orthogonal surrounds. GE data showed stronger overall BOLD responses near the pial surface compared to deeper layers, while GRASE data from anatomically matched ROIs did not. This may be attributed to larger BOLD effects from pial veins in GE compared with GRASE, with the latter being more sensitive to microvascular effects due to spin-echo weighting.

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16.434 **Non-monotonic Contrast Tuning in macaque area V4** Ilaria Sani[1](ilaria.sani@univr.it), Elisa Santandrea[1], Ashkan Golzar[2], Maria Concetta Morrone[3,4], Leonardo Chelazzi[1,5]; [1]Dept of Neurological, Neuropsychological, Morphological and Movement Sciences, University of Verona Medical School, Verona, Italy, [2]Department of Physiology, McGill University, Montréal, Québec, [3]Dept of Physiological Sciences, University of Pisa, Italy , [4]IRCCS Stella Maris, Calambrone, Italy , [5]Italian Institute of Neuroscience, Verona, Italy

Neurons in the visual system typically exhibit a sigmoidal increase of their firing with luminance contrast of the stimulus. Here we report the first evidence of the existence of visual neurons showing selectivity tuning for contrast. We recorded responses of individual neurons in macaque area V4d to a set of bar stimuli spanning a wide range of contrasts while the animals were engaged in an orientation discrimination task. First we characterized cells as having a monotonic vs. non-monotonic function. Then we explored the temporal dynamics of CRFs, using partially overlapping time windows. We found highly heterogeneous discharge patterns, with around 34% of the recorded cells showing a non-monotonic profile. These cells were selective for a specific range of contrasts (average full bandwidth: 2.79 ± 0.22 sem octaves), with maximal responses occurring for different contrast levels across the population (range: 1.1-76.55 % Michelson contrast). The collected evidence indicates that in V4 contrast is also encoded by bandwidth filters selective to contrast, similarly to color or orientation. Interestingly, contrast tuning emerged after a delay from stimulus onset, probably reflecting the contribution of a normalization pool of cells - a candidate physiological mechanism mediating automatic contrast gain. We speculate that selective tuning for contrast and the increase in non-monotonicity over time might improve contrast coding at the population level, probably useful to mediate categorization of stimulus contrast.

16.435 **A forward model of multi-voxel pattern analysis in primary visual cortex** Rachel Millin[1](rmillin@usc.edu), Bosco S. Tjan[1,2]; [1]Neuroscience Graduate Program, University of Southern California, [2]Department of Psychology, University of Southern California

Informational functional magnetic resonance imaging (fMRI) measures are widely used to infer the involvement of cortical areas in a particular task or phenomenon. One of the most popular of these methods, multi-voxel pattern analysis (MVPA) using linear support vector machine, quantifies the predictability of the presented stimulus based on the pattern of responses of a group of voxels. This method has been applied to the study of visual processing and perceptual learning in retinotopic visual areas. However, interpretation of MVPA results is limited by a lack of information about the bounds on decoding performance from feed-forward activity given the power of the analysis methods. To address this, we have developed a forward model of MVPA in primary visual cortex. This model begins with a representation of the V1 cortical surface and its mapping with the visual space (Rovamo and Virsu, 1984) and incorporates the Balloon Model (Buxton et al., 1998) to generate the BOLD response. Known components of BOLD signal are integrated, including spatial correlation in BOLD signal due to hemodynamic spread and the spatially and temporally correlated noise that is inherent in BOLD measurements. For each subject, signal-to-noise ratio and correlation structures were determined by tuning model parameters to achieve the best match between the BOLD-signal modulation during retinotopy and model output with retinotopic mapping stimuli as input. The model was then used to simulate BOLD fMRI data for letter stimuli presented at a given eccentricity, to be analyzed with MVPA. This model provides an upper bound for empirical MVPA performance if the observed BOLD signal is due to retinotopically organized feed-forward activity, and can thus aid in interpretation of MVPA results in retinotopic visual areas as due to predominantly feedforward versus post-stimulus activity such as feedback.

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16.436 **Increasing Velocity Postpones Responses Compared to Decreasing Distance with Time to Collision being Equivalent: Behavioural and Neural Evidence** You Li[1](nyunyo@qq.com), Pengfei Wang[1], Xiaozhe Peng[1], Qi Chen[1]; [1]Department of Psychology, South China Normal University

Spatial and temporal information must be integrated to predict the potential collision of two moving objects. It has been known that left inferior parietal cortex and bilateral sensorimotor cortex are involved in the judgments of time-to-collision (TTC) (Assmus et al., 2003, 2005; Field & Wann, 2005). In the present fMRI study, we aimed at investigating the potentially different contributions of the velocity and the distance dimension to the TTC judgments. The visual stimuli included one horizontally moving ball and one vertically moving ball. At the start of each trial, the horizontal ball started moving, and the participants were required to press a button to initiate the moving of the vertical ball at the most appropriate time so that the vertical ball could precisely hit the horizontal ball. We adopted another high-level control task in which the same set of stimuli was used and the participants were required to judgment the luminance change of the targets. More importantly, the distance and the velocity of the horizontal ball were parametrically varied. With the same four levels of time-to-collision (TTC), we either kept the distance constant and increased the velocity, or we kept the velocity constant and decreased the distance. Behavioral results showed that TTC judgment task performance significantly varied as a function of TTC. Moreover, with the velocity increasing, participants were more inclined to respond behind the theoretical time, compared with the distance-decreasing conditions. Imaging results showed that, the lingual gyrus, precuneus, and right middle frontal gyrus was specifically involved in the velocity-increasing conditions. More interestingly, lingual gyrus showed a parametric modulation effect both when velocity increased and when distance increased. Taken together, we showed that the two dimensions contributed differentially to TTC judgments at both the behavioral and the neural levels.

16.437 **A cortical locus for overlay suppression with broadband stimuli revealed through transcranial direct current stimulation**

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Human contrast sensitivity for Gabor targets is largely suppressed when superimposed on a Gabor mask of the same spatial frequency (SF) and orientation (referred to as overlay suppression, OS), with suppression being broadly tuned to orientation (~130° bandwidth) and spatial frequency (~3 octave bandwidth) (Petrov, Carandini, & McKee, 2005). Further, numerous behavioral and neurophysiological experiments have suggested that the suppressive signals leading to OS originate from the initial LGN inputs to V1. However, Kim, Haun, and Essock (2010) have reported anisotropic contrast sensitivity thresholds for differently oriented Gabor targets when masked by broadband noise. Their results suggest a much narrower orientation tuning for OS than would be expected if it originates from initial LGN inputs to V1, and imply that another cortical operation is active when overlay masks are broadband. Here, we sought to explore this notion using transcranial direct current stimulation (tDCS). Since tDCS is only effective at modulating cortical function, we hypothesized that tDCS would influence suppression for OS with broadband stimuli but not for OS with narrowband stimuli which may result from sub-cortical signals. Target stimuli consisted of 8cpd Gabor targets (subtending 0.3°) at one of three orientations (0°, 45°, or 90°). Overlay masks were either identical to the targets (narrowband masks), or consisted of broadband noise patches (20° orientation bandwidth and 2 octaves in SF). All masks were fixed at 0.21 rms contrast; with target contrast controlled by a standard 2IFC staircase procedure (stimulus duration was 150ms). Human participants performed the task foveally with tDCS (anodal and cathodal) and without (i.e., baseline). The results showed that tDCS resulted in a large anisotropic reduction in OS when the masks were broadband, but not when they were narrowband. This supports the hypothesis that OS has a cortical locus when the overlay masks are broadband in SF and orientation.

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16.438 **Assessment of Neural Mechanisms in Central Visual Function: A Visual Evoked Potential Study in Observers with and without Age-Related Macular Degeneration**

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A visual evoked potential (VEP) stimulus battery was developed and applied in a pilot study of adults with age-related macular degeneration (AMD) and adults with intact retinal function to explore neural mechanisms and pathways in central visual function. Adults with and without AMD were recruited from an ophthalmology clinic. Some individuals in both groups were tested with dilated pupils following standard clinic protocol, while others were tested prior to dilation. Testing conditions (10° square field, ~50cd/m2) were short (2-7s, condition dependent) and repeated ten times for statistical analyses. To elicit transient VEPs, a high-contrast 1Hz contrast-reversing 32x32 checkerboard was used. To elicit steady-state VEPs, the following conditions were used: high-contrast horizontal square-wave gratings contrast-reversed at 7.5Hz with spatial frequency swept in octave steps, isolated-checks (bright or dark) appearing/disappearing at 12.5Hz with contrast swept in octave steps, and radial partial-windmill and windmill-dartboard conditions with spatial elements contrast-reversed (32% contrast) at ~4Hz and surrounding regions set to a uniform field or static 32% contrast elements, respectively, for responses reflecting nonlinear short- and long-range lateral interactions. The electroencephalogram was recorded by a single channel with an active electrode over V1. Magnitude-squared coherence (MSC) was computed for response components extracted by Fourier analysis. Increased latencies and lower MSC values in transient VEPs were found in the AMD group, compared to controls. Spatial frequency functions demonstrated deficits at high spatial frequencies for the AMD group. Low contrast responses were not significant in many observers, possibly associated with pupil dilation. Short-range lateral interactions, presumably of GABAergic origin, were relatively intact in the AMD group, even when input signals to the cortex were weak. This stimulus battery, combined with objective response measures, yields sensitive indices of central visual function. Both magnocellular and parvocellular inputs to V1 appear compromised in AMD, while local intracortical inhibitory activity appears robust

16.439 **Magnetoencephalographic correlates of visible persistence in transient random-dot stimuli**

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Visible persistence (VP) refers to the perceived presence of a stimulus after its physical offset. Typically, it lasts for several tens of a second and is most prominent in briefly presented stimuli. To create an extreme case of VP, we successively presented two matrices of 600 x 600 randomly black and white pixels, where all pixels in an annulus-shaped region reversed polarity between the matrices while all other pixels remained identical. On the transition of the first to the second matrix the luminance flip created the perception of an annulus with an abrupt onset and a gradual offset lasting on average about one second. In a magnetoencephalographic study we presented 19 participants repeatedly with such single-transient-random-dot-stimuli and let them judge the subjective duration of visible persistence on each trial. Based on these trial-by-trial judgments we split the data post-hoc into trials with physically identical stimulation but subjectively short and long durations of VP. We therefore avoided confounding phenomenal differences with physical differences between experimental conditions. We compared evoked fields as well as time-frequency responses. Source analyses of evoked fields indicated that before stimulus onset a parietal cluster was more active in trials with long compared to short perceived durations, signaling a positive influence of attention on VP. This interpretation was supported by differences in the power of oscillations in the alpha-band between short and long trials, also located in parietal areas. Additionally, frontal electrodes showed differences in gamma-activity, suggesting that small eye movements contributed to the maintenance of a conscious percept in the absence of physical stimulation. We discuss the strength and limitations of our approach to obtain objective results about a subjective phenomenon.

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16.440 **Second-Order Neuronal Responses to Contrast Modulation Stimuli in Primate Visual Cortex**

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Responses to contrast modulation (CM) and other second-order stimuli have been extensively studied in human psychophysics and neurophysiology in the cat. However the neuronal substrates of second-order responses in non-human primates remain poorly understood. To address this issue we have recorded single neurons in area V2 of anesthetized, paralyzed, carefully refracted macaque monkeys, using both CM stimuli as well as conventional luminance modulation (LM) gratings presented on a linearized CRT monitor. CM stimuli were constructed from stationary sinewave grating carriers, which were modulated by drifting envelope gratings of a lower spatial frequency. Initially using envelope parameters matched to each neuron's optimal LM grating, we systematically varied carrier spatial frequency at a series of carrier orientations. About one-third of visually responsive V2 neurons responded to CM stimuli with a pronounced selectivity to carrier spatial frequencies that were clearly outside the neuron's passband for LM gratings, and therefore genuine second-order responses rather than luminance artifacts. Many of these neurons were also quite selective to carrier orientation; different neurons were selective for different carrier spatial frequencies and orientations. Using carrier parameters optimized for each neuron, we verified that tuning to CM envelope spatial frequency and orientation was very similar to that for LM gratings. Neurons were tuned to carrier spatial frequencies that were typically 2-4 octaves higher than their optimal envelope spatial frequencies. These results are distinct from CM responses arising from surround suppression (Tanaka & Ohzawa, J Neurophysiol, 2009; Hallum & Movshon, VSS, 2011), which show optimal carrier/envelope frequency ratios of about two. However they more resemble previous human psychophysics for CM (Sutter et al, Vis Res 1995; Dakin & Mareschal, Vis Res, 2000) and some other kinds of second-order stimuli (Kingdom & Keeble, Vis Res, 1999; Meso & Hess, Vis Res 2010), which are best detected at higher carrier/envelope frequency ratios.

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16.441 **Increasing efficiency of fMRI retinotopic mapping using Maximum Length Sequences** Daniel Berman[1](berman.72@osu.edu), Xiangrui Li[1], Zhong-Lin Lu[1], Dirk Walther[1]; [1]Department of Psychology, The Ohio State University

Visual cortex is organized in a series of retinotopic maps. Functional magnetic resonance imaging (fMRI) is routinely used to establish the correspondence between locations in the visual field and the activity of specific pieces of cortical tissue in response to visual stimulation of these locations. The standard stimulus for this type of mapping consists of a rotating wedge and an expanding ring, establishing the polar angle and eccentricity of each voxel's preferred location. This stimulus is conceptually simple and ensures orthogonality of the time courses of stimulation at each visual field location. However, the wedge/ring technique does not make optimal use of scan time. Depending on the specifics of the design, each portion of visual cortex is being stimulated for only about one quarter or less of the total scan time. Here we demonstrate a new, more efficient way of mapping spatial receptive fields of voxels in early visual areas. The stimulation of each segment of visual field, defined by polar angle and eccentricity, is controlled by a Maximum Length Sequence (MLS) of ones and zeros. Since an MLS is essentially orthogonal to itself when shifted in time (autocorrelation zero everywhere except at t=0), we use shifted versions of the same MLS for each visual field location. This procedure ensures orthogonality of the stimulation sequences while stimulating each location for half of the total scan time on average. In computer simulations we have found a significant increase in efficiency, which is reflected in higher accuracy of the receptive field mapping when using the same scan time as for the wedge/ring stimulus, or in a decrease of the scan time required to achieve the same accuracy. In fMRI experiments we compare the results of both types of stimuli within subjects, thus verifying the predictions of our computer simulations.

16.442 **Transcranial Direct Current Stimulation over Posterior Parietal Cortex alters Perceived Position** Jessica Wright[1](jessica@vision.rutgers.edu), Bart Krekelberg[1]; [1]Center for Molecular & Behavioral Neuroscience, Rutgers University

Regions in posterior parietal cortex (PPC) have been implicated in visuospatial processing and attention. The hemispheric rivalry theory (HRT) (Kinsbourne 1977, 1993) proposes that the allocation of attention is governed by mutually suppressive interactions between parietofrontal circuits in the two hemispheres. Consistent with this, previous research has shown that right PPC damage results in various visuospatial deficits such as hemispatial neglect and that transcranial direct current stimulation (tDCS) over PPC reduces line bisection errors in spatial neglect subjects. In the current study, we combined psychophysical methods with tDCS to determine how PPC affects a centroid estimation task in healthy human subjects. We applied tDCS bilaterally, e.g. cathodal stimulation over right PPC concurrent with anodal stimulation over left PPC (right-cathodal) or vice versa (left-cathodal). After 15 minutes of tDCS, subjects located the centroids of briefly presented one-dimensional dot arrays. Based on the assumption that cathodal stimulation suppresses neural activity; the HRT leads to the hypothesis that right-cathodal tDCS should shift the perceived centroid rightward. Preliminary results show that (1) tDCS alters centroid estimation in healthy human subjects; (2) Consistent with the HRT, the right-cathodal configuration shifts the perceived centroid more to the right relative to the right-anodal configuration, this effect lasts up to 15 minutes and (3) Both tDCS conditions shifted the perceived centroid to the left of a sham stimulation baseline. This effect was still measurable 20 minutes after stimulation offset. These findings provide support for the causal role of PPC in position perception, and the asymmetric effect of stimulation supports the HRT hypothesis. The surprising finding that both tDCS conditions altered perceived position similarly relative to a baseline condition suggests that tDCS does not simply increase or decrease PPC activity in a polarity dependent manner.

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16.443 **Impaired mechanisms of suppression in amblyopia** Eunice Yang[1](euniceyang@berkeley.edu), 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 often accompanied by suppression of visual signals from the weaker eye. Physiological studies of amblyopia suggest that intracortical inhibition may play a role in mediating amblyopic suppression. We investigated whether other suppressive phenomena tied to intracortical inhibition are also impaired in amblyopia. Specifically, we measured the magnitude of surround suppression, overlay suppression, and interocular suppression in amblyopes and healthy controls, using well-established psychophysical measures. When a stimulus with surround mask was presented to amblyopes' dominant eye (DE), perceived contrast of that stimulus was reduced, and the magnitude of surround suppression was comparable to that of controls. In contrast, surround suppression associated with the amblyopic eye (AE) was significantly stronger in comparison to the DE and to control subjects. In our overlay suppression task, contrast detection thresholds were measured for a Gabor patch embedded in noise relative to when it was presented alone. Elevations in contrast thresholds were significantly lower when the masked Gabor patch was presented to the AE in comparison to the DE, consistent with previous findings. In contrast, overlay suppression measured with amblyopes' DE was comparable to that of controls. Finally, we used flash suppression to measure elevations in contrast increment discrimination thresholds for an eye when it was suppressed relative to when it was dominant. In line with previous studies, amblyopes showed a significant imbalance in interocular suppression relative to controls, which was attributed to diminished flash suppression of the DE by the AE. The magnitude of surround suppression and to a weaker extent, interocular suppression was predictive of the severity of amblyopia, as indexed by interocular differences in acuity. Our results are consistent with physiological evidence that amblyopia is associated with heightened GABAergic inhibition and that surround and interocular suppression, but not overlay suppression, are most likely mediated by intracortical inhibition.

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16.444 **Efficacy of pupil responses elicited to grating stimuli for detection of visual processing in hemianopia** Arash Sahraie[1](a.sahraie@abdn.ac.uk), Mary-Joan MacLeod[2], Ceri T. Trevethan[1], Larry Weiskrantz[3]; [1]Vision and Attention Laboratories, School of Psychology, College of Life Sciences and Medicine,University of Aberdeen, [2]School of Medicine and Dentistry, College of Life Sciences and Medicine, University of Aberdeen, [3]School of Psychology, Department of Experimental Psychology, University of Oxford

Sudden onsets of grating patterns even in the absence of additional light flux components result in a transient constriction of the pupil, the amplitude of which varies as a function of the spatial frequency in healthy adults, resembling the contrast sensitivity function. The existence of pupil grating responses for stimuli presented within the blind field of a hemianopic patient and two hemi-decorticated monkeys were reported previously. Importantly, the findings matched the characteristics of psychophysically determined spatial channel of processing in the same patient. The findings led to the suggestion that pupillometry may be utilised as an objective technique for detection of visual function within the field defect. We have systematically investigated the presence of a spatial channel of processing in the blind field of 19 hemianopic patients using a psychophysical forced-choice technique and obtained the corresponding pupil responses at a range of spatial frequencies. In addition, in 13 cases we determined the pupil responses in a sighted field location matching the blind field eccentricities. Our findings demonstrate that blindfield pupil responses are similar to those for the sighted field, but attenuated in amplitude on average by half a log unit. All those cases with a significant pupil response to a 1 cycle/degree grating patch (n=11) also showed a significant blind field detection, determined psychophysically. 6 cases without any significant pupil responses also did not perform above chance in the psychophysical detection of grating patterns. There were however, three cases that had significant psychophysical response in the absence of a significant pupil response. It remains to be determined whether these minority cases could be associated with particular extent or locus of lesions. Pupillometry correctly characterised the presence or absence of a significant psychophysical response, in 85% of cases and thus is worth examining in the cortically blind fields as predictor of intact psychophysical capacity.

16.445 **Edge-based versus region-based texture perception: does the task matter?** Cassandra Diggiss[1](cassandra.diggiss@mail.mcgill.ca), Frederick A. A. Kingdom[1]; [1]McGill Vision Research unit, Department of Ophthalmology, McGill University

Aim: Studies of texture segregation have suggested that some types of textures are processed by 'edge-based' and others by 'region-based' mechanisms (e.g. Wolfson & Landy, Vis. Res., 1998). On the other hand, studies using nominally 'edge-based' textures have found evidence for region-based processing when the task was to detect rather than to segregate the textures (Kingdom & Keeble, Vis. Res., 1996). Here we investigate directly whether the nature of the task determines if region-based or edge-based mechanisms are involved in texture perception. Method: Stimuli consisted of randomly positioned Gabor micropattern texture arrays with three types of modulation: orientation modulation (OM), contrast modulation (CM) and luminance modulation (LM). Each modulation type was defined by three types of waveforms: sine-wave (SN), square-wave (SQ) and cusped-wave (CS). The CS waveform was constructed by removing an equal-amplitude sine-wave from a square-wave. The SN textures had only smooth variations, whereas the SQ and CS waveforms had sharp texture edges, but with different texture energies. Subjects performed two tasks. In the detection task subjects selected which of two stimuli contained the modulation. In the discrimination task subjects indicated which of two textures with slightly different texture-bar orientations contained leftward-oriented bars. Results: At low texture spatial frequencies threshold amplitudes in the detection task followed the rule SQ <SN <CS, as would be expected if all the texture energy available was used for detection, and suggesting that the task was region-based. However, for the discrimination task the order was SQ similar to CS and both less than SN, suggesting that the texture edges were the more salient features. At medium and high texture spatial frequencies the two tasks produced comparable results. Conclusion: A change in the task from detection to discrimination can under some circumstances cause texture processing to switch from being region-based to edge-based.

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Object recognition: Spatial and temporal aspects

Friday, May 10, 5:30 - 8:00 pm

Poster Session, Orchid Ballroom

16.446 Does viewpoint dependency effect influence scene consistency effect?

Kazuhiko Yokosawa[1](yokosawa@l.u-tokyo.ac.jp), Gergo Sastyin[1], Ryosuke Niimi[1]; [1]The University of Tokyo

We examined the effect of object viewpoint on perception of natural scenes comprising one object against a background. The consistency of objects and backgrounds greatly influences object recognition (Palmer, 1975; Hollingworth, & Henderson, 1998). Davenport and Potter (2004) also reported that recognition of an object facilitates perceptual processing of its background and vice versa: this is the scene consistency effect. This effect holds even for brief scene exposures. Based on these results, Davenport and Potter presented an interactive recognition model for simultaneous object and background processing. Object recognition is also strongly influenced by the viewpoint from which an object is observed. We hypothesized that the scene consistency effect does not occur for objects observed from an accidental viewpoint; instead, the latter should decrease efficiency of object recognition. We tested the scene consistency effect using canonical and accidental views of objects (i.e., canonical/accidental conditions). The semantic consistency of objects with backgrounds was also manipulated (consistent/inconsistent conditions). Participants viewed briefly presented scenes and named either objects (Experiment 1) or backgrounds (Experiment 2). Results of Experiment 1 showed a significant scene consistency effect, i.e., object naming accuracy was higher in the consistent condition. We also found a significant viewpoint effect (lower accuracy for accidental views). However, no interaction was observed between these two factors; regardless of object viewpoint, a scene consistency effect was always present during the object recognition task. Results of Experiment 2 replicated the scene consistency effect for the background naming task. However, the difference due to object viewpoints completely disappeared; object viewpoint showed no effect on the background naming accuracy. These asymmetrical results in object and background processing imply that scene perception is not always mutually interactive as Davenport and Potter proposed.

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16.447 Unmasking the Mask: Semantic Similarity Produces Disinhibition in a Masked Priming Paradigm

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Observers are typically unaware of masked stimuli, but they can become aware of them when they are"unmasked" by subsequent stimuli that mask their mask. In such cases the masked stimulus is considered "disinhibited." Here we show that a masked word can be disinhibited when it is semantically similar to a stimulus that follows its mask. A briefly-exposed word (50 ms) was preceded by a forward mask (300 ms) and followed by a 60-ms backward mask. The backward mask was followed by a silhouette (175 ms) depicting either a nameable real-world object or a novel object. There were two types of novel silhouettes: (1) experimental novel silhouettes suggested portions of real-world objects on their groundside (of which participants were unaware), and (2) control novel silhouettes that did not suggest a real-world object on their groundside. The masked words either matched (i.e, named) or mismatched the real-world objects portrayed by real world silhouettes or suggested on the groundside of experimental novel silhouettes. The words preceding the control novel silhouettes also named real-world objects. On each trial, participants reported whether they saw a word and if so, whether it named the subsequent silhouette. Participants were more likely to see words preceding real-world silhouettes in the match condition (%40) versus all other conditions (~%15; $p<0.05$). Thus, the masked word was more likely to be disinhibited by a semantically similar real world silhouette, supporting a dynamical view of masking in which semantic processes can play a role. In previous research we showed that semantics are accessed for real-world objects suggested (but not perceived) on the groundside of experimental novel silhouettes. Here semantic access for objects suggested by grounds did not interfere with masking, showing that access to semantics is weaker for real-world objects suggested on the groundside rather than the figure side of a border.

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16.448 Passively viewing a manipulable object activates its specific action representation: Evidence from a behavioral study

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There is increasing evidence that gestural knowledge of manipulable objects is an important part of object representation and plays a role in object identification. What remains unsolved is under what condition functional manipulation information is evoked. While studies from brain imaging supported the view that passively viewing a manipulable object is sufficient to activate its action-related information (Creem-Regehr & Lee, 2005; Wadsworth & Kana, 2011), behavioral research proved the opposite: activation of gestural knowledge is task-dependent and only could be evoked when participants attend to manipulable objects (Bub & Masson, 2006; Vainio, Ellis & Tucker, 2007). In the present study, a priming paradigm was used to explore if passively viewing manipulable objects could be enough to activate specific action information about how to use them. The experiment contained four conditions: congruent manipulability, incongruent manipulablity, the control and the unrelated, which depended on the relation of manipulation knowledge between the primes and the targets. Participants were required to conduct an object identification task by pressing the keyboard. The results showed that the target objects with similar manipulation representation to the prime objects were identified significantly faster than the pairs with dissimilar manipulation knowledge. The manipulation congruence effect was attributed neither to the visual similarity between the prime object and the target object, nor to the familiarity of the primes among the four conditions. To our knowledge, this was the first evidence by using behavioural study to indicate that just passively viewing a manipulable object was sufficient to activate its specific use-related manipulation representation that could facilitate object identification even without participants' intention to use them. The results provided additional support to the interaction between ventral and dorsal visual pathways. The importance of manipulation knowledge in object represeatation will also be discussed.

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16.449 The Landmark Expansion Effect: Navigational Relevance Influences Memory of Object Size

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Humans often use visual objects as landmarks to navigate through their environment. Several qualities of an object can make it useful as a landmark; for example, (i) being positioned at a navigationally relevant decision point, or (ii) being large and stable. Is there a common representational code for these landmark properties? To investigate this question, we presented subjects with a movie depicting a route through a virtual museum, with objects placed at intersections (navigational decision points) or at simple turns (non-decision points) along the route. They were asked to pay particular attention to half of these objects, indicated by the category vehicle or animal. Following learning, subjects performed a magnitude estimation task in which they judged the size of the objects on a scale of 1-9. Although the actual size of the decision and non-decision point objects was matched, we found that objects previously encountered at decision points were remembered as being larger than objects previously encountered at non-decision points. In contrast, the attentional manipulation had no effect on remembered size. This finding indicates that there is a common representational code for the properties that make an object a landmark, such that if an object attains salience as a landmark by having one of these properties, is it more likely to be remembered as having another as well. Based on previous neuroimaging work showing that the parahippocampal place area (PPA) responds strongly to both objects at navigational decision points (Janzen & Van Turrenout, 2004) and to large objects independent of their explicit navigational utility (Konkle & Oliva, 2012; Mullally & Maguire, 2011), we suggest that the PPA is the neural locus of this common landmark code (Troiani et al., in press).

16.450 **MoonBase: Generating a database of two-tone "Mooney" images**

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Thresholded two-tone ("Mooney") images are of interest for vision science because the object hidden within the image can be hard to recognize, with recognition times in the second to minute range. However, once a subject has seen the original grayscale image from which the Mooney is generated, recognition is much accelerated. Typically, suitable "Mooney" images need to be painstakingly generated by hand. Here, we present an approach for automatically generating a two-tone image database. This is based on large number of images collected from the internet. We first selected concrete words from a linguistic database. Using these words as search words, we automatically downloaded images from an online image database (www.flickr.com). Subsequently, the images were preprocessed and thresholded using a histogram based thresholding algorithm to generate the two-tone images. We provide an image set with 330 Mooney images and psychophysical results obtained from six subjects. With a presentation time of 20 s, the average recognition time was 9.36 s ± 7.40 s. Additionally, subjective ratings (confidence, Aha, and difficulty ratings) were obtained and are presented for each subject and image. This image set is, to our knowledge, the largest two-tone image set available to the vision and cognitive science research community (https://sites.google.com/site/hayneslab/links). We provide a Matlab toolbox that makes the extension of the image database possible. Using this toolbox, the researcher can add new object names as search words and create new two-tone images easily. Furthermore, we will present possibilities to extent this toolbox using another image database called ImageNet and introduce the use of Amazon Mechanical Turk to select useful images for a particular experiment. This image database can be useful for studying the mechanisms of rapid learning of visual image recognition, and has applications in research on conscious vision, learning, priming, reward and insight.

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16.451 **Fingerprint Matching Expertise and its Determinants**

Gennady Erlikhman[1](gennady@ucla.edu), Tandra Ghose[2], Patrick Garrigan[3], Jennifer Mnookin[4], Itiel Dror[5], David Charleton[5], Philip Kellman[1]; [1]Department of Psychology, University of California, Los Angeles, [2]Department of Psychology, University of Kaiserslautern, Germany, [3]Department of Psychology, St. Joseph's University, [4]School of Law, University of California, Los Angeles, [5]School of Psychology, University of Southampton

Purpose: Fingerprint evidence plays an important role in forensic science. Informal observation and some research suggests that experts attain high levels of proficiency in determining whether two fingerprints match; typically this involves matching a partial or distorted image obtained from a crime scene (a latent print) with a print from a database (a tenprint). Like expertise in many other complex classification tasks, such as identifying pathology in radiographic images or classifying of birds by experienced birdwatchers, fingerprint expertise depends heavily on perceptual learning involving discovery and fluent extraction of structural features in varying contexts (Gibson, 1969; Kellman & Garrigan, 2009). Little research has examined what kinds of information are used by expert examiners to achieve advanced performance. Method: We compared the performance of expert examiners, novices, and novices who watched a short training video on a fingerprint matching task. Participants reported whether a latent and tenprint were from same or different sources. They also gave ratings of confidence in their responses and ratings of difficulty for each presented pair. Results: Experts were more accurate and had stronger correlations between difficulty and accuracy ratings than both groups of novices, whose performances were comparable. Approximately twenty image features, including mean local contrast and ridge reliability were extracted for each print pair and used as predictors of accuracy in a regression model. By comparing the multiple regression models for each group, we found that novices who watched the training video shared more predictors with the experts than the other group of novices. Conclusions: Our results suggest that level of expertise in fingerprint matching is correlated with learning to properly combine the right types visual information when making a fingerprint match. These results support the importance of perceptual discovery in attaining expertise and have implications for development of training interventions for fingerprint matching.

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16.452 **Basic dimensions of subjective experience of beauty**

Slobodan Markovic[1](smarkovi@f.bg.ac.rs); [1]University of Belgrade, Department of Psychology

The purpose of the present study was to specify the underlying structure of subjective experience of beauty. In preliminary study 1 a set of twelve photographs of various visual objects and scenes was selected (humans, animals, landscapes, buildings etc). In preliminary study 2 a set of eighty representative descriptors of subjective experience of beauty was selected (e.g. pleasant, elegant, cute, magnificent etc). In the main study twenty-one participants judged twelve stimuli using a check-list of eighty descriptors. Using Osgood's 'stringing-out' method a unique matrix of judgments was created. A factor analysis (principal component method plus Promax rotation) extracted six basic dimensions: Cuteness (most saturated descriptors: cute, sweet, nice, tender, etc), Fascination (fascinating, fantastic, fabulous, delightful, etc), Grandiosity (grandiose, eternal, monumental, magnificent, etc), Elegance (elegant, sophisticated, graceful, neat, etc), Relaxation (relaxed, calm, idyllic, peaceful, etc) and Attractiveness (attractive, handsome, seductive, satisfying, etc). The relationship between these dimensions was specified through a Multidimensional scaling analysis of their inter-correlations. A two-dimensional solution revealed the dimensions which could be identified with two aspects of emotions. Dimension 1 referred to hedonic tone. It included two clusters on its poles: (1) Cuteness, Relaxation and Attraction on the positive pole (higher hedonic tone) and (2) Grandiosity, Elegance and Fascination on the negative pole (moderate hedonic tone). Dimension 2 referred to arousal. It encompassed two clusters: (1) Attraction and Fascination on the positive pole (higher arousal), and (2) Elegance and Relaxation on the negative pole (lower arousal). These results suggested that the complexity of the experience of beauty (six dimensions) could be reduced to two more basic aspects, that is hedonic tone and arousal.

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16.453 **Exogenous Attention Improves Object Recognition Without Affecting Apparent Contrast**

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The effect of selective attention on object recognition remains largely unexplored. Here, we test whether selective attention enhances viewers' ability to recognize objects with an object-naming task. We control the amount of object information within a given object image by gradually scrambling the Fourier phase. In this manner, we obtain a set 8 different images for each object, each having a coherence level ranging from 30% to 100%. At the start of each trial, a small red dot probe is presented on either side, or on both sides of fixation in order to direct exogenous attention, followed by a brief presentation of two object images with an equal level of coherence. At the end of the trial, subjects were asked to identify the object depicted within one of these 2 images. Trials were classified as neutral if probes appeared on both sides of fixation. Congruent and incongruent trials were classified depending on whether the location of the queried image matched the location of the probe. We find a significant effect of attention when the object stimuli are presented at 70% coherence and no difference otherwise between attention conditions. In a second experiment, we test whether the observed difference in performance can be attributed to the modulation in perceived contrast reported using similar paradigms. We tested this hypothesis by attempting to null the predicted effects of exogenous attention on perceived contrast. Therefore, for congruent trials we decrease the contrast of the queried image by 10%, 20%, 30%, 40%, or 50%. For incongruent trials, we increase the contrast of the queried image by the same amount. We find no effect of contrast modulation on the attentional effect from experiment 1. These results suggest that the effect of exogenous attention on object recognition cannot be attributed to modulation of perceived contrast.

16.454 **Dissociating intuitive physics from intuitive psychology in adults with Williams syndrome** Daniel D. Dilks[1](dilks@mit.edu), Joshua B. Julian[1,2], Peter W. Battaglia[3], Nancy Kanwisher[1]; [1]McGovern Institute for Brain Research, MIT, [2]Department of Psychology, University of Pennsylvania, [3]Department of Brain and Cognitive Sciences, MIT

Evidence from developmental studies suggests that our understanding of how things work (often referred to as 'intuitive physics') and our understanding of how people work (i.e., social perception/cognition – sometimes referred to as 'intuitive psychology') are two 'core domains' of human cognition (e.g., Carey, 1985). Here we directly test the dissociability of these two domains by investigating adults with Williams syndrome (WS) – a rare genetic developmental disorder which gives rise to an unusual cognitive profile of severe spatial deficit with relatively spared language. Adults with WS and typical control adults were tested on an intuitive physics tasks, in which participants had to judge whether a 3-second video of an unstable tower of blocks will topple over to the left or right (Hamrick et al., 2011). A category control task also asked for high-level judgments on short silent movie clips, but in this case, the judgments were social: participants had to judge whether a child in a 3-second video is interacting/playing with another person (off camera), or is playing alone (Balas et al., 2012). If intuitive physics is a distinct domain (from intuitive psychology), then we predict differential impairment on the "towers" task for WS adults relative to typical adult controls. Indeed, preliminary evidence shows disproportionate impairment in the intuitive physics (towers) task compared to the intuitive psychology task in WS adults, relative to typical controls. This result indicates that our knowledge of the physical world can be disrupted independently of intuitive psychology, and further suggests that the distinction between these two domains has a genetic basis. Future studies will ask i) whether individuals with autism show the opposite profile from WS, for a full double dissociation, and ii) whether intuitive physics is implemented in specialized brain circuits.

Acknowledgement: Grant EY13455 to NK and a Simons Foundation Autism Research Initiative (SFARI) postdoctoral fellowship to DDD

16.455 **Adaptation to the summary variance of a visual array** Elizabeth Michael[1](elizabeth.michael@psy.ox.ac.uk), Vincent de Gardelle[2], Christopher Summerfield[1]; [1]Dept. Experimental Psychology,University of Oxford, Oxford, UK, [2]CNRS UMR 8158, Laboratoire Psychologie de la Perception, Paris, France

Recent evidence suggests that observers encode information about the central tendency of a visual array independent of details about individual features. For example, thresholds for judging the mean difference between two arrays of circles are equivalent to or lower than those for comparing two isolated circles. However, human performance on perceptual averaging tasks is sensitive to the variability (or heterogeneity) of visual information independent of the mean. Here, to ask whether observers automatically encode summary information about the variability of visual information in a scene, measured reaction times (RTs) on a task in which observers judged the average shape or colour of a target visual array that was preceded by an irrelevant prime array. Manipulating the mean and variability of the feature information on prime and target arrays orthogonally, we observed an interaction whereby a highly variable prime array led to faster RTs for a subsequent high variance target, and a less variable prime facilitated RTs to low-variance targets. This facilitatory variance-adaptation effect occurred with prime-target intervals as short as 100ms. A control experiment introduced variance on a task-irrelevant dimension and showed that the results were considerably stronger in the decision-relevant dimension. This variance-adaptation effect, which resembles previously reported adaptation to response conflict between sequential trials, suggests the existence of a mechanism by which the range or dispersion of visual information is rapidly extracted. This information may in turn help to set the gain of neuronal processing during perceptual choice.

Acknowledgement: Medical Research Council (UK), European Research Council

16.456 **Subitizing occurs across features of a single object** Katharine B. Porter[1](kporter@fas.harvard.edu), Annie Garofalo[1], Veronica Mazza[2], Alfonso Caramazza[1,2]; [1]Department of Psychology, Harvard University, [2]CIMeC, University of Trento

'Subitizing' refers to the rapid and accurate ability to enumerate small sets of objects (1-4) with a significantly smaller cost in reaction time for each additional object than in larger object sets. The processes underlying this phenomenon are still under debate. One popular theory suggests that a fixed number of object-tracking 'fingers of instantiation' or FINSTs allow for pre-attentive selection of objects, facilitating the speedy enumeration of object sets up to the available number of FINSTs (Pylyshyn 1989). This theory suggests that subitizing would not occur over features, since FINSTs mark proto-objects without carrying knowledge of their properties. Evidence shows that subitizing does not occur while enumerating features such as color and orientation (Watson, Maylor, & Bruce 2005). However, features such as color and orientation do not intrinsically contain information about spatial boundary, a quality that has been shown to be important in number judgments (Franconeri, Bemis, & Alvarez 2009). Here we investigate the presence of subitizing during the enumeration of object features that hold unique points in space, yet are not spatially segmented from each other. In a series of behavioral experiments, participants were asked to enumerate control displays containing 1-8 spatially distinct shapes, as well as test displays of 1-8 spatially connected protrusions. We looked for evidence of subitizing in both conditions based on statistically greater slopes for larger numerosities than those in the subitizing range. We observed subitizing for both test and control conditions, indicating that subitizing can occur across features such as protrusions from a single object.

16.457 **Is confidence amodal? Confidence comparison across dimensions of a visual stimulus** Vincent de Gardelle[1](vincent.gardelle@gmail.com), Pascal Mamassian[1]; [1]Laboratoire de Psychologie de la Perception, Université Paris Descartes, Paris, France

Introduction: Our perceptual judgments in everyday life or in laboratory experiments are always accompanied with an introspective, subjective feeling of confidence: for a given response, we can estimate whether we have just given a random guess, or whether we are certain about the choice. However, the characteristics and mechanisms of these confidence judgments are still poorly understood. Here, we ask in particular whether confidence judgments in human observers are made in an abstract and generic frame of reference, or whether they are specific to a task. Methods: On each trial, observers were presented with two Gabor patches and had to judge both the change in orientation (clockwise vs. counter-clockwise) and spatial frequency (low-to-high vs. high-to-low) across the two patches. Then they had to report which perceptual decision (i.e. along which stimulus dimension, orientation or spatial frequency) was associated with higher confidence. Results: Observers' ability to discriminate two orientations (or two spatial frequencies) naturally increased with the orientation (spatial frequency) difference between the two Gabor patches. Critically, we found that confidence judgments interacted with perceptual performance: perceptual decisions associated with high confidence choices formed a psychometric function with a steeper slope. To further characterize this interaction between confidence choices and discrimination sensitivity, we assessed the efficiency of confidence judgments by deriving the ideal observer performance in this procedure. Conclusion: Human observers have the ability of judging and comparing confidence across different discrimination tasks applied to the same stimulus. This finding demonstrates that there is an amodal (i.e. task-independent) component to confidence evaluation. Future studies will aim at assessing whether confidence is fully or only partially amodal, by assessing the potential cost (in terms of metacognitive efficiency) of a switch between two dimensions during the confidence comparison judgment.

Perceptual organization: Shapes, objects

Friday, May 10, 5:30 - 8:00 pm

Poster Session, Vista Ballroom

16.501 **Neural Correlates of Spatiotemporal Boundary Formation (SBF)** Gideon Caplovitz[1](gcaplovitz@unr.edu), Gennady Erlikhman[2], Jay Lago[1], Philip Kellman[2]; [1]Department of Psychology, University of Nevada, Reno, [2]Department of Psychology, University of California, Los Angeles

Purpose: In spatiotemporal boundary formation (SBF), surface boundaries, object shape, and global motion are perceived from sequences of local element changes (Shipley & Kellman, 1994a, 1994b). It has previously been suggested that SBF uses sequential changes as motion signals, and these feed into a computation that determines edges and eventually form (Shipley & Kellman, 1996). A model built on these assumptions is sufficient to model human performance in an edge discrimination test where the edges are defined by SBF (Erlikhman et al., 2012). However, no previous work has examined the neural correlates of SBF. Method: In a series of experiments, we applied EEG techniques to examine the neural timecourse of the formation of a shape representation in SBF displays. In one condition, four SBF shapes defined by color changes of small dot elements traveled on a circular path. In a control condition, the same number of changes occurred on every frame, but the sequence of the changes was randomized and no SBF shapes are perceived. We collected EEG data from 10 subjects. Results: The difference waveform elicited by subtracting the event related response to the control stimuli from that to the SBF stimuli consisted of a significant negative component from 200-300ms followed by a significant positive component from ~300-400ms. Control experiments were performed to test the hypothesis that the earlier component reflects the extraction of the motion signals necessary for SBF (e.g., Kuba & Kubova, 1992) and the later component reflects the subsequent formation of the perceived shapes produced by SBF.

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16.502 **Seeing and liking: Biased perception of ambiguous figures based on aesthetic preferences for how objects should face within a frame** Yi-Chia Chen[1](yi-chia.chen@yale.edu), Brian Scholl[1]; [1]Department of Psychology, Yale University

Aesthetic preferences are ubiquitous in visual experience. Indeed, it seems nearly impossible in many circumstances to perceive a scene without also liking or disliking it. While aesthetic factors are occasionally studied in vision science, they are often treated as something that occurs only after the rest of visual processing is complete. In contrast, the present study explores whether aesthetic preferences influence other types of visual processing — focusing on the disambiguation of bistable figures. We used bistable images whose competing interpretations differed not only in their semantic content (e.g. duck vs. rabbit) but also in the direction they appeared to be facing (to the left vs. to the right). Observers viewed one such figure at a time, placed within a visible frame — near the left edge, near the right edge, or in the center — and they pressed a key to indicate which interpretation they saw throughout each 15-second trial. Previous work with unambiguous images identified an "inward bias": when an object is near the border of a frame, we like the image more if the object is facing inward (toward the center) vs. outward. When observers in the present project viewed a bistable figure, its position within the frame influenced what they saw at the beginning of each trial. For example, seeing a rightward-facing figure (whether duck or rabbit) was most likely when the figure was near the left border, and least likely when near the right border. The same pattern held for the total duration of each percept throughout a trial. In sum, observers tended to see whichever interpretation would cause the figure to be facing inward — i.e. whichever they would like more. We discuss the roles of attention and familiarity in such effects, and conclude that aesthetic factors play an active role in visual processing.

16.503 **Perceptual and conceptual disorganization in schizophrenia: Two sides of the same coin?** Brian Keane[1,2,3](brian.keane@gmail.com), Jamie Joseph[4], Steve Silverstein[1,2]; [1]Department of Psychiatry, UMDNJ–Robert Wood Johnson Medical School, [2]University Behavioral HealthCare, UMDNJ, [3]Center for Cognitive Science, Rutgers University, New Brunswick , [4]Graduate School of Biomedical Sciences, UMDNJ-Rutgers, New Brunswick

Background. People with schizophrenia are impaired at representing Kanizsa shapes, but why? Here, we hypothesize that the impairment arises at late processing stages, and is intimately related to disorganized thinking. Method. To consider the hypothesis, we had 13 healthy controls, 17 patients with disorganized schizophrenia, and 54 patients with non-disorganized schizophrenia engage in a "fat/thin" discrimination task (Ringach & Shapley, 1996). Subjects determined on each trial whether four individually rotated pac-men formed a fat or thin rectangle (illusory condition), or whether four downward pointing pac-men were all rotated to the left or right (fragmented condition). Half of the trials in each condition incorporated distractor lines, which disrupt discrimination when appearing near illusory contours but which can be ignored otherwise. Task difficulty depended on the amount by which pac-men were individually rotated to create the response alternatives, where larger rotations made for an easier classification. Performance was assessed with an adaptive staircase and threshold corresponded to the amount of rotation needed for 80% accuracy. Shape integration was measured as the threshold difference between the illusory and fragmented conditions (without distractors); a lower relative illusory threshold signifies better integration. Results. Distractor lines raised thresholds more in the illusory than in the fragmented condition ($p<.001$). This interaction did not depend on participant group ($p>.7$), suggesting that illusory contour formation was intact in all groups. However, disorganized patients were worse at shape integration than non-disorganized patients ($p=.03$) who in turn were marginally worse than controls ($p=.07$). Conclusion. People with schizophrenia form illusory contours but they are not able to use those contours to normally discern global shape. Shape integration impairments are especially pronounced among conceptually disorganized patients. These findings, taken together, show that schizophrenia entails a high-level visual integration deficit that is fundamentally related to disorganized thought.

Acknowledgement: F32MH094102

16.504 **The influence of visual working memory on correspondence in the Ternus display** Elisabeth Hein[1](elisabeth.hein@uni-tuebingen.de), Andrew Hollingworth[2], Cathleen M Moore[2]; [1]Department of Psychology, Universty of Tübingen, [2]Department of Psychology, University of Iowa

Introduction: Surface feature continuity plays an important role in the perception of an object as a single, persisting entity across change and disruption. For example, color can be used to establish object correspondence across motion, occlusion, and eye movements. However, the underlying mechanisms of feature-based object correspondence are not well understood. Here, we tested the hypothesis that visual working memory (VWM) maintains feature information used to solve the correspondence problem under conditions of ambiguous apparent motion. Method: We used the Ternus display, in which three adjacent discs were presented. After a variable inter-stimulus interval (ISI), the discs were shifted horizontally by one position. Across displays, the correspondence among discs was ambiguous. The discs could be perceived as moving together as a group (group motion) or as one disc jumping across two stationary discs (element motion). Participants indicated the form of motion they perceived. To examine whether the content of VWM modulates the correspondence operation, the discs were assigned colors that could bias the percept either toward group motion or element motion. In addition, participants maintained a color in VWM to prepare for a memory test. The memory color matched either the color of the Ternus discs biasing group motion, the color of the discs biasing element motion, or neither. Results and conclusion: Consistent with previous studies, the proportion of group motion responses increased with increasing ISI. More importantly, the memory color influenced perceived motion. Relative to the no-match baseline, observers were more likely to perceive element motion when the memory color matched the element bias and more likely to perceive group motion when the memory color matched the group bias. These results suggest that feature-based object correspondence is mediated by the content of visual working memory.

16.505 **Visual aftereffects in natural object categories** Isamu Motoyoshi[1](motoyoshi.isamu@lab.ntt.co.jp); [1]NTT Communication Science Laboratories, NTT

We recently showed that adaptation to a realistic 3D object with a particular shape and material alters the appearance of the subsequent object (Motoyoshi, VSS 2012). The aftereffect is robustly induced even by adapting to synthetic stimuli such as band-pass noise, and to stimuli at remote spatial locations (Motoyoshi, ECVP 2012). These findings raise a possibility that the perception of 3D shape and material is based on a neural population of low-level image features represented within a large receptive field at high levels. Using this object aftereffect (OAE), the present study examined whether such image-based coding is also relevant for object categorization, the primary goal of ventral visual processing. Observers were shown with one of 20 morphed photographs between an apple and a pear, and were asked to classify it into 'apple' or 'pear'. The morphing level that gave 50% apple/pear response was defined as her/his categorical boundary between the two. We found that adaptation (4 sec) to one extreme (e.g., apple) caused an apparent shift in the boundary toward the other (e.g., test image at the boundary appeared a pear), even when the test stimulus was presented at non-adapting locations. The aftereffect was also caused, though weakly, by adapting to a texture, synthesized with Portilla-Simoncelli's algorithm, that had similar image statistics with those of apple or pear and was outlined by the either's contour shape. The amount of the aftereffects depended on the combination of texture, contour shape, and category; the adaptor with apple's silhouette and apple-like texture had the largest effect. These results support a notion that a population of low-level features within a large receptive field, which is analogous to 'bag of keypoints' in machine vision, plays a significant role not only in shape and material estimation, but also in object recognition by humans.

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16.506 **The Perceptual Processes Underling the Representation of Impossible Objects.** Erez Freud[1,2](Erezfreud@gmail.com), Bat Sheva Hadad [1,3], Galia Avidan[1,2], Tzvi Ganel[1,2]; [1]Department of Psychology Ben-Gurion University of the Negev, Beer Sheva, Israel., [2]Zlotowski Center for Neuroscience, Ben-Gurion University of the Negev, Beer Sheva, Israel., [3]Department of Education, University of Haifa, Israel

Impossible objects are 2D drawings that represent objects that could not exist in real space. Yet, despite being perceived as exceptionally unusual, they still possess fundamental Gestalt attributes, such as closure and volume properties which are known to mediate holistic representation. In Experiments 1 and 2, we used Garner's speeded classification task to test this notion. Results showed that participants were unable to processes one dimension of possible and impossible object's shape while ignoring task-irrelevant dimensions belonging to the same objects. These findings suggest that the shape of impossible objects is processed in a configural manner and are in-line with recent neuroimaging findings (Freud, Ganel, Avidan; 2012) that showed that possible and impossible objects are processed by shared neural mechanisms, alongside differences between the two objects categories that were attributed to late cognitive processes. Experiments 3 and 4 were therefore aimed to test whether the initial perception of impossible objects involves similar perceptual mechanisms to those underlying typical object perception and that any perceptual differences obtained between the two object categories would only emerge later along the processing hierarchy. Experiment 3 utilized the object-based attention paradigm to show that impossible and possible objects are represented similarly such that processing features belonging to the same object was enhanced compared to features belonging to two different objects. Yet, responses for impossible objects were overall slower. Experiment 4 was designed to examine whether this difference could be attributed to late processing stages by manipulating exposure duration. Importantly, differences in accuracy between possible and impossible objects emerged only for long stimulus exposures thus verifying our working hypothesis. Overall, these findings suggest that the visual system utilizes intact shape attributes to create an object-based, configural representation of impossible objects and highlight the importance of these attributes for early stages of perceptual organization.

16.507 **Shape-Induced Distortions of Spatial Judgements** Galina Goren[1](galinagoren@gmail.com), James H. Elder[1]; [1]Centre for Vision Research, York University, Toronto, ON, Canada

Biases in the judgement of lengths in the plane abound; examples include the Muller-Lyer illusion and the vertical-horizontal illusion. Here we demonstrate a new form of bias induced by shape. There are two reasons to predict such a bias. First, some theories hold that a shape is neurally represented as a deformation process. Such a mechanism might induce artifactual distortions in the perceived metric structure of the image. Second, if the shape induces a 3D percept, this might bias 2D judgements. Methods. Observers are presented with a triplet of points, in proximity to the outline of an animal shape. Each triplet forms an isosceles right-angle triangle with a horizontal long side. Although the two oblique sides are equal, observers are asked to judge which appears shorter. Interpreting each judgement as a distortion of the perceived triangle, from a sequence of trials we derive a vector field of perceived distortion over the image. In a control condition, observers make the same judgements in the absence of the outline shape: the difference in the resulting vector fields provides an estimate of distortion independent of static inhomogeneities of the visual field. Results. For three of four observers, distortion was found to be significantly larger inside the shape (figure) than outside the shape (ground), and in these same three observers, the distortion grew larger nearer the contour. For two of the observers distortion was significantly biased to flow radially out from the centre of the shape in both figure and ground regions; for the other two observers this radial bias was significant only for the ground region. Conclusion. These results show that shape outlines can induce distortions in the image. These distortions may be artifacts induced by cortical mechanisms for shape representation, or illusions based on 3D perceptual interpretations of the image.

16.508 **Go Figure: Individuation vs. Configuration in Processing Spatial Arrays** Amy M. Clements-Stephens[1](aclemen5@jhmi.edu), Amy L. Shelton[1]; [1]Johns Hopkins University

Previous studies have suggested that the strategies one employs when organizing visual-spatial information may shift during development. Specifically, prior studies indicate that adults more accurately reproduced visual-spatial arrays that promoted configural processing compared to displays that promoted individuation of elements, whereas children showed the reverse pattern. However, in hidden search tasks, when children were provided with a meaningful shape, they searched more efficiently than with random shapes, suggesting that children may prefer a configural strategy but require meaningful shape to utilize configuration (Uttal et al., 2001). The present study tested whether meaningful shape can facilitate layout reproduction of small-scale visual-spatial configurations via manipulating both the global shape (meaningful vs. random) and color (monochromatic vs. multicolored) of displays. Children 6-12 years of age and adults reproduced four different displays and we measured the degree of distortion in each reproduction. Adults showed a main effect for color (monochrome better than multicolored) and a trend for display type (meaningful better than random), indicative of a configural approach. By contrast, results for the children revealed an effect of display type (meaningful configurations less distorted than random arrays) and an interaction between display type and color. An interrogation of the interaction revealed that adding meaningful shape enhanced performance on the monochromatic condition but had no effect on the multicolored condition. Together, this finding suggests that (1) children may more naturally utilize information that promotes individuation of array elements; however, (2) meaningful shapes can confer an advantage as represented by an attenuation of the difference between monochromatic and multicolored displays for the meaningful shape condition. Overall, these results may reflect a tension between strategy use in children and that although they may not spontaneously adopt a configural strategy, when configural information is the only information conveyed it can be used to more efficiently represent visual-spatial arrays.

16.509 **A crescent edge-length illusion induced by object-based perception** Xiang Huang[1](psy.lemonhuang@gmail.com), Jun Yin[1], Rende Shui[1], Mowei Shen[1]; [1]Department of Psychology and Behavioral Sciences, Zhejiang University, Hangzhou, P.R.China

Objective: The features of figures are not perceived independently in visual images but are influenced by their contexts, for example, the Jastrow illusion. Here we reported a new visual illusion which reflects the influence of higher level object configuration on its local features. Methods: In five experiments, participants were required to adjust the length of a straight line until its length equalized to a target curve's length. Target curve was set to be the concave (50% of trials) or convex (50% of trials) edge of a crescent shape (the length of concave edge is shorter than that of convex edge; Experiments 1, 2, 3, and 4), or one of the two separate curves of a decomposed crescent shape (Experiment 5). Results: A novel length illusion was revealed: When crescent objects were the tested stimuli (Experiments 1-4), a curve was perceived shorter when being as the convex edge than being as the concave edge. In contrast, when the two separated curves were the tested stimuli (Experiment 5), a contrast effect was revealed: The length of a curve was perceived shorter when being as the shorter one of the two separated curves than being as the longer one. Conclusion: The results suggest that the object-based perception affects the length perception of crescent edges. It is rather strong such that it overwhelms the contrast effect emerging in the separate-curves condition.

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16.510 **Interactions between surface material and perception of angular velocity of rotating 3D objects** Gizem Kucukoglu[1], Laurence Maloney[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Purpose: Ho et al (2008, Psych Science) examined how changes in one material property – gloss – affect perception of a second – roughness — and v.v. We examine how perception of angular velocity is affected by the surface material – glossy or matte – of a rotating object. In this work we investigate the relationship between material and motion by looking at the effect of material properties on the perception of the angular velocity of rotating rigid 3D virtual objects. Methods: Objects were smooth, irregular shapes resembling potatoes rendered under a point light source. They were either shiny or matte and rotated at angular velocities between 60 deg/sec and 420 deg/sec. On each trial the subject saw a pair of rotating objects – one shiny, one matte – presented one after the other. The subject's task was to judge which object in the pair rotated faster. We used a staircase method to adjust the angular velocity of one object in each pair until it appeared to be rotating as rapidly as the other. Nine subjects completed the experiment (1 other subject was excluded due to lack of convergence in staircases). Results: The data reveal an overall bias towards perceiving matte objects to be rotating relatively faster than shiny ($t7 = -2.8885$, $p = 0.0234$). That is, if a matte and shiny object appear to be rotating at the same

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angular velocity, the matte object is objectively rotating more slowly. The bias was 34 degrees per second. Conclusion: We find a large effect of surface material on perception of angular velocity consistent with the findings of Kucukoglu, Fleming & Doerschner (2010, VSS) for linear motion.

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16.511 Robust shape perception of static and rotating objects revealed by spatiotemporal form integration J. Daniel McCarthy[1](mcdan27@gmail.com), Gideon P. Caplovitz[1]; [1]Cognitive & Brain Sciences, University of Nevada, Reno

To perceive moving objects, the visual system must integrate form and motion information across space and time. Form and motion perception have historically been considered independent processes, but research repeatedly demonstrates that these processes interact in many complex ways. Spatiotemporal form integration (SFI) describes the process by which the visual system is able to integrate shape information over space and time to form percepts of stationary and moving objects. Illusory figures revealed by sequentially presented inducers are an excellent example of this integration process. It remains unknown, however, under what precise temporal and rotational constraints SFI can support static and moving figures. Here, we use adaptive staircase procedures to compare perception of SFI completed figures to standard Kanizsa figures using a wide range of timing parameters. Results indicate that under the wide range of conditions tested, participants show similar discrimination ability for spatiotemporally completed figures compared to standard Kanizsa figures. Additionally, participants made directional judgments on rotating SFI illusory squares and demonstrate that SFI supports moving illusory square percepts up to a maximum angular displacement of 6º - 7º between successive inducers. We conclude that the visual system can retain and update local and global form information over space and time periods exceeding the upper limits of iconic memory leading to percepts of stationary, as well as moving objects. This integration process is likely embodied within visual areas KO, LOC and hMT+ (McCarthy, Kohler, Tse & Caplovitz, VSS 2012). Importantly, these percepts are as robust as percepts of other forms of illusory figures.

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16.512 Bites & bends: Interpreting the visual meaning of concavities Patrick Spröte[1](patrick.sproete@googlemail.com), Roland Fleming[1]; [1]University of Giessen, Germany

When we observe objects, we not only infer local 3D-surface properties like depths or curvatures, but we can also make judgments about the generative processes that formed the shape. In many cases, we can decompose the perceived shape into two distinct contributors – the original shape and a transformation subsequently applied to it. For example, a croissant's concavity is perceived to be the result of a 'bending transformation' applied to a piece of dough, whereas the concavity in a bitten cookie is interpreted as due to an excision process in which a portion of the cookie has been removed. Although similar in shape, the visual system assigns different causal origins to the concavities of the cookie and the croissant. This in turn can have substantial effects on the perceived symmetry axis of the object. How the visual system interprets concavities therefore plays an important role in the perceptual organization of shape. We investigated factors that influence the 'visual meaning' of concavities in shapes and thereby the perceived causality. First, we used an asymmetric matching task to test whether subjects could identify bending transformations applied to arbitrary shapes. Subjects indicated how strongly they perceived a test shape to have been bent by applying the same perceived amount of bend to a different match shape. In a second experiment, we specifically determined which geometric factors distinguish perceived bites from bends. Subjects saw shapes that were either bent or bitten, along with a dot indicating some location in the shape. Subjects indicated the corresponding 'symmetric point' across the perceived axis of symmetry. Their judgments were used to evaluate perceived symmetries and causal processes that generated the concave shapes. By changing the regularities of shapes and the relationships between shapes and their concavities, we map out key geometrical factors affecting the visual meaning of concavities.

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16.513 Quantifying Kitaoka's enhanced checkered illusion Dejan Todorovic[1](dtodorov@f.bg.ac.rs), Marija Milisavljevic[1]; [1]Laboratory of Experimental Psychology, Department of Psychology, University of Belgrade, Serbia

The enhanced checkered illusion (Kitaoka, 2007) involves a pattern of checks that contain pairs of small squares (inductors) centered at one diagonal of the checks, near their opposite corners. The presence of inductors generates an apparent tilt in the orientation of the lines formed by the edges of the checks. The illusion is compelling (see http://www.michaelbach.de/ot/geom_KitaokaBulge/index.html), but little is known about its cause or relation to other tilt illusions. We studied how the illusion is affected by the position of the inductors, luminance polarity of checks and inductors, and distance of observation. The stimuli were circular insets of 18x18 enhanced checkerboards (sides of checks: 9.4 mm; sides of inductors: 1.9 mm), at five levels of rotation (-2, -1, 0, 1 and 2 degrees from vertical), each in two symmetrical mirror versions, observed from two distances (far: 100cm, near: 50cm). The task was to judge whether the orientation of the near-vertical edges of the checkerboard was tilted clockwise or counterclockwise. We obtained psychometric functions of percentage 'clockwise tilt' judgments against degree of rotation. In Experiment 1 the check/inductor pattern was lightgray/black vs. darkgray/white. We varied the gap between the sides of the inductors and the sides of the checks, which was either zero, intermediate (0.9 mm), or large (1.8 mm). For the far observation distance the strongest illusion was found for the intermediate gap, it was weaker for the zero gap, and absent for the large gap. For the near observation distance the illusion was only present for the intermediate gap. In Experiment 2 we found illusory effects of similar strength for checkerboards with the black/white vs. white/black check/inductor pattern and checkerboards with the darkgray/lightgray vs. lightgray/darkgray pattern, but no effect for checkerboards with the darkgray/black vs. lightgray/white pattern. The results provide constraints for physiologically based theories of the illusion.

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16.514 Accessing meaning for the groundside of a figure: How long does it last? Laura Cacciamani[1](lcacciam@email.arizona.edu), Andrew J. Mojica[1], J. L. Sanguinetti[1], Mary A. Peterson[1]; [1]University of Arizona

Regions on opposite sides of borders compete for figural status, with the winner perceived as figure, and the loser perceived as shapeless ground. Peterson et al. (2012) tested whether the meaning of a familiar object that loses the competition is accessed prior to figure assignment—a finding that would refute traditional feedforward views. Participants categorized words as naming natural or artificial objects. Before each word, a novel silhouette with a portion of an upright familiar object suggested along the groundside of its borders appeared. Participants perceived the inside of this silhouette as the figure and were unaware of the familiar object suggested on the groundside. With an 83-ms silhouette-to-word SOA, participants categorized words faster when the object suggested on the groundside was of the same versus a different category as the word. Because differences in border curvilinearity between silhouettes suggesting natural versus artificial objects on their groundsides may have been responsible for those effects, in the current experiment we used inverted as well as upright silhouettes. Inversion should eliminate semantic access effects but leave border curvilinearity effects unchanged. Additionally, we tested longer SOAs to investigate how long facilitation lasts. At a 166-ms SOA, words following upright silhouettes were categorized faster when the unperceived familiar object in the ground was of the same versus a different category as the word ($p < .01$), replicating Peterson et al. This facilitation was not observed for inverted silhouettes ($p > .40$), demonstrating that our effects are due to activation of the semantics of the familiar objects on the groundside rather than to silhouette border curvilinearity. By a 250-ms SOA, semantic facilitation for upright silhouettes was no longer evident. This study shows that the meaning of potential objects that lose the competition for figural status is accessed prior to figure assignment, contrary to traditional assumptions.

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16.515 Underestimation of numerosity in dynamic visual display Ricky K. C. Au[1,2](ricky@fennel.rcast.u-tokyo.ac.jp), Katsumi Watanabe[1]; [1]Research Center for Advanced Science and Technology, The University of Tokyo, [2]Japan Society for the Promotion of Science

Previous research suggested that the estimation of numerosity of a large number of objects is possible even with a short presentation of static visual display. The present study examined the estimation of numerosity of objects presented in a sequence and whether it would be modulated by the availability of attentional resources. In Experiment 1, two streams of events (each 960 ms) showing dots of the same shape and size were presented in each trial. In one stream, two dots of different colors (red and green) were presented at random locations on an imaginary ring in each frame (40 ms) of a stream, resulting in 24 frames. In the other stream, either one, two or three dots of the same color (red or green), varied across a range of "percentage of frames with one (or three) dots", were presented in each frame. Observers were asked to judge which of the streams contained a

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greater number of dots. The results showed that the observers judged the stream with same-color dots contained a less number of dots than the different-color stream. This difference disappeared when a slow presentation speed (240 ms/frame) and static visual displays were used. In Experiment 2, observers performed a dual-task in each trial: numerosity judgment task and target detection task with different levels of attentional load (number of targets to be reported). The data revealed that the task difficulty of the dual-task has a remarkable influence on how precisely the observers performed the numerosity judgment task, but the underestimation effect associated with the same-color stimuli remained evident even in the dual-task conditions. These results suggest that identical objects presented in succession might induce substitution among themselves, leading to a perception of being less numerous overall; and that exploiting the availability of attentional resources does not eliminate this underestimation effect.

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16.516 **Measuring Configural Superiority with the Capacity Coefficient** Joseph Houpt[1](joseph.houpt@wright.edu), Robert Hawkins[2], Devin Burns[2], James Townsend[2]; [1]Department of Psychology, Wright State University, [2]Department of Psychological and Brain Sciences, Indiana University, Bloomington

Configural superiority effects are an important component of our understanding of visual perception of many types of stimuli. We propose the capacity coefficient as common framework for measuring configural superiority across a wide range of stimulus types. This measure has a number of advantages. The coefficient is based on a comparison of responses to the configuration with a baseline of unlimited-capacity, independent, parallel processing of each of the parts. Response times for processing the parts in isolation are used to estimate that baseline performance. Better than baseline performance, or better than unlimited-capacity, independent parallel processing, of a configuration of parts, indicates configural superiority. Furthermore, because the capacity coefficient accounts for the difficulty of processing each part, the capacity coefficient for one type of configuration can be compared to the capacity coefficient of another configuration, even if the parts are not exactly the same. We applied the capacity coefficient to three domains in which configural superiority effects have been previously demonstrated: the orientation of a pair of dots, words, and faces. We found that participants had better than baseline performance for detecting differences in the location of dots relative to reference points if there was also a difference in the orientation. The capacity coefficient was much higher than when there was not a difference in orientation; in fact, when there was no difference in orientation, the capacity coefficient indicated worse than baseline performance. Likewise, we found that participants performed better than baseline with words. Participants' capacity coefficients were higher for words than random consonant sequences, which tended to have equal to or worse than baseline capacity coefficients. Finally, we found that participants had better than baseline performance with aligned upper and lower face halves, but lower capacity coefficients with misaligned face halves, usually below baseline.

Acknowledgement: NIH-NIMH

16.517 **Hemispheric specialization for symmetry processing is complexity dependant** Jason Bell[1](jason.bell@anu.edu.au), Anne Wentworth-Perry[1], Andrew Isaac Meso[2], Ben Thompson[3]; [1]Research School of Psychology, Australian National University, Australia, [2]Institut de Neurosciences de la Timone, CNRS & Aix-Marseille Université, France, [3]Department of Optometry and Vision Science, University of Auckland, New Zealand

Symmetry is a fundamental characteristic of objects and scenes, one that human observers are highly sensitive to. Moreover, observers are faster and more accurate in detecting symmetrical stimuli compared with asymmetric versions, in the left visual field but not in the right (Wilkinson & Halligan, 2002). This has been taken as evidence for a right hemisphere advantage in symmetry processing. The present study investigated whether this hemispheric advantage is affected by the complexity of the visual feature. Stimuli were familiar block shapes and random walk contour paths constructed from Gabor patches. The former are likely to tap mid-level form processing mechanisms while the latter are thought to be processed in V1. Stimuli were randomly presented 6° to the left or right of a central fixation cross, for 160ms. The observer responded as to whether the stimuli were horizontally symmetrical or asymmetrical. Fourteen participants were tested in each experiment. Experiment 1 replicated a left visual field symmetry advantage for familiar shape stimuli. Interestingly however, for contour paths a significant symmetry advantage, (faster RTs & lower error) was present in both visual fields. Experiment 2 showed that the symmetry advantage persisted for vertical and diagonal contour paths, judged relative to horizontal and oblique symmetry axes, respectively. Finally, Experiment 3 found that for paths composed of either: a) Gaussian blobs or, b) hard-edged discs, the symmetry advantage was drastically reduced. This suggests that the composition of the elements mediates performance. Our findings reveal that symmetrical contours are preferentially processed in both visual hemispheres. This holds for cardinal and oblique axes but is mediated by the spatial-frequency profile of the path elements. Taken as a whole our findings imply that symmetry is bilaterally advantaged in early visual processing while for more complex stimuli, this symmetry advantage is right hemisphere specific.

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Attention: Capture

Friday, May 10, 5:30 - 8:00 pm
Poster Session, Vista Ballroom

16.518 **Saccadic Inhibition of Return After Attention Shifts to Relevant and Irrelevant Color Singletons** Ulrich Ansorge[1,2](ulrich.ansorge@univie.ac.at), Heinz-Werner Priess[1], Dirk Kerzel[3]; [1]Faculty of Psychology, University of Vienna, Austria, [2]Institute of Cognitive Science, University of Osnabrueck, Germany, [3]Faculté de Psychologie et des Science de l'Éducation, Université de Genève, Genève , Switzerland

We tested whether color singletons lead to saccadic and manual inhibition of return (SIOR and IOR) and whether SIOR and IOR depended on the relevance of the color singletons. In altogether four experiments (Experiments 1 to 4), we observed SIOR after color singletons, and in two additional experiments we also found manual IOR for pointing movements (Experiment 5) but not for manual button presses (Experiment 6). Across experiments, SIOR and IOR increased with reaction time (RT) and tended to be stronger with long (Experiment 1) than short intervals (Experiment 2 to 5) between color singleton and saccade target. In addition, stronger SIOR after irrelevant than relevant singletons was only found when the interval between color singleton and saccade target was relatively short (Experiments 3 and 4). Together, the results shed light on some factors responsible for SIOR and help to understand some inconsistencies in the literature on top-down contingent capture of attention and its relation to SIOR and manual IOR.

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16.519 **Some effects of non-predictive cues on accuracy are mediated by feature-based attention** Josef G. Schönhammer[1](josef.schoenhammer@unige.ch), Dirk Kerzel[1]; [1]Université de Genève

The current research asks whether involuntary attention is a control mechanism of attentional resource allocation or a set of decision bias mechanisms. Frequently, involuntary attention is investigated with spatially non-predictive cues. There is evidence that non-predictive cues have no effect on accuracy when location uncertainty is eliminated, suggesting that involuntary attention is not connected to resource allocation. Our experiments asked whether a top-down set for specific target features results in resource allocation to non-predictive cues. Thus, even though the cueing effects could be classified as involuntary, effects might be mediated by top-down feature-based attention. Over a block of trials, cues or targets were defined by a unique onset or a unique color, and the dependent measure was accuracy. In Experiment 1, effects of cue validity were obtained when both cue and target were onsets or color-defined, but not when they were different. Experiment 2 ruled out alternative explanations (Prinzmetal, McCool, & Park, 2005) by presenting the cue after the target, which eliminated cueing effects. Experiment 3 examined the possible impact of priming of pop-out features. On each trial, cue and target were equally likely to be onset or color-defined, but observers made responses only to either onset or color targets. When cue and target were onsets, the cueing effect did not change as a function of the target type on the previous trial, suggesting that priming of pop-out had no influence. When cue and target were color-defined, neither cueing effects nor any impact of the target type on the previous trial was obtained, suggesting that with the current manipulation observers did not adopt a top-down set for a specific color.

16.520 **Recent experience in a fixed search mode reduces the influence of explicit search strategies** Zachary J. J. Roper[1](zachary-roper@uiowa.edu), Shaun P. Vecera[1]; [1]Department of Psychology, University of Iowa

An observer's current search mode is driven by top-down set and previous experience. According to behavioral measures, attention defaults to singleton detection mode; however, observers are inclined to explicitly report searching in feature mode. We assessed whether the persistence built by recent experience is reflected in explicit report. We operantly conditioned observers to perform a search task while in singleton detection mode or feature search mode. Observers then completed an option mode test condition where a singleton distractor was equiprobably present or absent. We witnessed greater attentional capture due to the distractor's presence when observers were trained in singleton detection mode. These results accord with previous findings which show the tendency to persist using the most-recently activated search mode when the option is available. Self-report measures revealed that observers did not have a clear understanding of their own behavior. There were no differences between self-reported "oddball" searchers and feature searchers when trained in singleton detection and feature search mode. A third group of observers were trained in an option mode where either feature search or singleton detection modes could be used. Capture in this group did not significantly differ from the other two groups; however, a further split of the option group between self-reported "oddball" searchers and feature searchers revealed a correspondence between self-report strategies and behavioral outcomes. Observers who reported searching for a feature were captured to the same extent as observers who were trained in feature search mode; whereas observers who reported searching for an "oddball" were captured to the same extent as observers who were trained in singleton detection mode. These results suggest that recent experience directs current behavior by de-emphasizing the implementation of explicit search strategies.

16.521 **Hand position modulates attentional capture** Daniel Vatterott[1](daniel-vatterott@uiowa.edu), Shaun Vecera[1]; [1]Psychology Department, College of Liberal Arts and Science, University of Iowa

Observers are faster to respond to targets near the hands than far (Reed et al., 2006), which demonstrates preferential processing of items near observers' hands, but it is unclear if this preferential processing can override stimulus-driven attentional capture. To investigate if capture is influenced by hand position, observers completed the additional singleton paradigm (Theeuwes, 1992) with either their left or right hand near the screen. In the additional singleton paradigm, observers search for a shape singleton among homogenous distractors. Critically, on half the trials one of the distractors is a different color making it an additional singleton. Although this item is irrelevant to the task, observers are slower to respond to the target when the additional singleton is present. In the current experiments, if the attentional effects of hand position influence capture, then hand position might prevent or reduce capture when a salient stimulus appears far from the hand. Conversely, if stimulus-driven capture is impenetrable to body-based influences, , then capture would occur irrespective of the proximity of a salient stimulus to the hand. Our results confirm the former hypothesis, demonstrating that color singletons near the hand slowed response times to the target, $t(15) = 2.4$, $p <. 05$, whereas color singletons far from the hand did not, $t(15) = 1.2$, $p > .24$. These results suggest that the magnitude of stimulus-driven capture is affected by hand position.

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16.522 **It's about time! Capture and disengagement from temporal attentional capture and how they are affected by visual working memory capacity** 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

In a number of experiments we investigated individual differences in attentional capture (i.e., the influence of irrelevant outer stimuli on attentional control). Previous findings have dissociated the initial capture effect (i.e., orienting attention to the distractor) and the subsequent release from capture process (i.e., when attention moves away from the distractor), and demonstrated that individuals with low visual working memory capacity (VWMC) show sluggish recover times from capture relative to high capacity individuals. Yet, both high and low capacity individuals were equally vulnerable to the initial capture effect. Importantly, the study tested the spatial capture and release from capture processes (because the distractor was presented in a different spatial position relative to the target). In the current study we investigated the connection between VWMC and temporal attentional capture, in which all stimuli were presented at the same location, one after the other. We tested the degree to which a distractor, occasionally presented several intervals before the target, interfered with the target processing. Contrary to previous studies, we found that low-capacity individuals displayed more capture than high-capacity individuals (an effect that was found when the distractor and the target were from different categories), but there were no differences in their recovery time from capture. When we increased the task difficulty (by using three response categories rather than using only two), we found a connection between VWMC and recovery time from capture. Namely, while high-capacity individuals recover faster from temporal capture, low-capacity individuals are slower to recover and keep being engaged by the distractor even at long distractor-to-target intervals. The present results together with pervious findings suggest that the disengagement from capture reflects an attention based cognitive ability that plays an important role in individual differences in VWMC.

16.523 **Motion fails to capture attention. But onset of motion succeeds.** Fook Chua[1](fkchua@nus.edu.sg); [1]Psychology, National University of Singapore

There is clear evidence that onset of motion captures attention, but it is less clear whether motion, itself, captures attention. This set of experiments investigated attention capture by moving objects with the spatial cuing paradigm. An irrelevant dynamic-singleton cue was presented before the appearance of the search array. Capture was assessed by locating the target in the same, or a different, place as the cue. If cue and target were in different locations, and the cue captured attention, attention would have to be redeployed away from the cue, and to the target. If cue and target occupied the same location, the extra shift may be obviated, thereby facilitating performance. The experimental sequence contained 3 main frames: (1) fixation frame, which established the search letters' positions. Each of these critical locations was surrounded by four spots. (2) cue frame, in which the dynamic irrelevant cue was presented. The motion of one set of spots constituted the irrelevant cue. (3) a search frame, in which the target and distractors were presented. The contrast was between (a) spots that continued to revolve, while the other spots ceased their motion (continuous-motion condition) and (b) spots that only started to move when the cue frame appeared (motion-onset condition). In separate experiments, we manipulated the type of dynamic discontinuity that defined the target's location. When the target letter appeared as an abrupt onset, or was the lone rotating letter, capture was observed in the motion-onset condition. There was either no capture (target onset) or weak capture (target rotates) for the continuous-motion condition. It was not previous motion that undermined the capture capacity of the continuous-motion cue. When the surround spots changed their motion from winking on-and-off to rotating around the placeholder at cue presentation, they successfully captured attention.

16.524 **Resisting Attentional Capture by an Additional Singleton Depends on Prior Experience With Its Salient Feature** Tashina Graves[1](tgrave15@jhu.edu), Howard Egeth[1]; [1]Department of Psychological and Brain Sciences, Johns Hopkins University

During the search for a shape singleton, a salient color singleton can capture attention. The state of being set to search for any singleton is referred to as singleton detection mode. Capture will not occur if participants are searching for a specific shape among a variety of shapes, so-called feature search mode. Trials where participants search for a specific shape singleton are considered option trials because either singleton detection or feature search could be used to find the target. Despite the viability of both strategies, singleton detection mode appears to be the default because the color singleton captures attention. However, if participants trained with feature search trials are given option trials at test, capture will not occur on the option trials. It appears that feature search mode transfers from the training trials to test trials where participants would otherwise use a singleton detection strategy. Previous studies have shown that if you change the color of the salient color singleton from training to test, there is no transfer--the new color singleton will capture attention. In this study, we kept the color singleton consistent and varied other factors. In one experiment we used different sets of shapes for training and test, and in another we changed the shape set as well as the color of all items except for the color singleton. In both cases, the salient color singleton captured attention at test if participants had had singleton detection training, but not if they had had feature search training. Thus, it appears that the ability to resist capture on option trials depends on previous experience ignoring the specific feature of the distracting item, and not on experience attending to the features of the target.

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16.525 **Effect of prior knowledge on competition for representation and attentional capture** Matthew Hilimire[1](mrhilimire@wm.edu); [1]College of William & Mary

When multiple objects are present in a visual scene, salient and behaviorally relevant objects are selectively processed at the expense of less salient or irrelevant objects. Here I used three lateralized components of the event-related potential – the N2pc, Ptc, and SPCN – to examine how objects compete for representation in our limited capacity visual system, and how task-relevant objects are selectively processed. Participants responded to the orientation of a color singleton target while ignoring a color singleton distractor. Competition between the objects was manipulated by presenting visual search arrays that contained only a target, only a distractor, or both objects together. In Experiment 1, observers did not know the color of the target in advance, whereas in Experiment 2 this information was provided. Experiment 3 was a control experiment to rule out low-level sensory explanations of the effects. The results suggest that the N2pc component indexes capture of attention by salient objects which is modulated both by competition between the objects and top-down knowledge. The Ptc component may index inhibition of return so that once an object is processed it is not selected again. The SPCN component may index enhancement of goal-relevant objects once task-irrelevant objects have been suppressed. Together these lateralized event-related potentials reveal the temporal dynamics of competition and selectivity in the human visual system.

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16.526 **Do Negative Emotional Pictures Automatically Capture Attention?**

James Hoffman[1](hoffman@udel.edu), Kelsey Holiday[1], McKenna Erin[1]; [1]Department of Psychology, University of Delaware

Emotion-induced blindness (EIB) refers to impaired awareness for items that appear soon after an irrelevant, emotionally arousing stimulus. . In previous research, we used event-related brain potentials (ERPs) to study the mechanisms responsible for EIB. We found that emotional distractor pictures elicited two ERP components that were related to the magnitude of EIB: the N2, which is thought to reflect attentional engagement, and the Pd which appears to index attentional disengagement. The current research investigates whether these components are automatic or require attention. Previous research has produced mixed results on the question of whether the N2 component elicited by negative pictures is affected by attention while the Pd component has not been examined. We addressed the automaticity of these components by requiring participants to perform a multiple object tracking (MOT) task on objects moving in front of a stream of rapidly presented pictures (outdoor scenes and cityscapes). Earlier research showed that MOT abolished awareness for scene pictures appearing in a stream of distractors. Our streams also sometimes contained a "distractor" picture that could be negative (dangerous animals, mutilated bodies, etc.) or neutral (people and animals in nonemotional settings). When observers attended to the picture stream, distractors produced robust N2 and Pd components. In contrast, when they performed the MOT task and attempted to ignore the pictures, the N2 associated with distractors was suppressed while the Pd components increased in amplitude. These results show that the N2 component elicited by distractor pictures is sensitive to attention and is reduced when attention is occupied by another task. In contrast, the Pd component is enhanced when salient distractors are ignored which is consistent with the claim that this component reflects a process responsible for preventing or terminating attentional engagement.

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16.527 **Faces, emotions, & distraction: Dissociating attentional capture vs. hold**

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A critical function of attention is to direct focus to salient stimuli in the environment. The "saliency" of a stimulus is sometimes defined by basic physical attributes (e.g., high contrast visual feature), but attentional biases may also be driven by more complex sets of features and characteristics. Such highly salient stimuli can capture and potentially hold attention, leading to distraction. The mechanisms by which highly salient, yet irrelevant, stimuli lead to distraction, however, are not well understood. Here, we investigated how a particularly strong type of distractor - images of human faces expressing fear - involuntarily bias attention. Across three experiments using a novel continuous performance task and behavioral measures of accuracy and reaction time, we find that increased distraction is not associated with an enhanced attraction to faces, but instead reflects an extended hold of attention on faces. Specifically, the initial onset of a distractor impaired target performance regardless of the identity of that distractor (i.e., picture of a face or picture of a place). In contrast, an extended period of distraction was observed only when the distractor was a face. Whereas previous work has highlighted the human tendency to preferentially attend to faces, the current results refine the mechanism by which this unique bias may occur: an extended dwelling of attention on faces. Critically, however, the holding of attention by faces was not dependent on the emotional expression on the face, occurring for neutral faces as well as for fearful faces. Furthermore, whereas the initial capture of attention to the sudden onset of a distractor occurred regardless of context (i.e., consistent distractor type vs. mixed distractor type), the presence of an extended holding of attention was dependent on the ongoing distractor context, providing further evidence to dissociate reflexive capture and attentional hold.

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16.528 **Multiple attentional control set in rapid serial visual presentation**

Jun Kawahara[1](jkawa@lets.chukyo-u.ac.jp), Takatsune Kumada[2]; [1]Department of Psychology, Chukyo University, [2]RIKEN BSI

Studies have shown that visual target identification is impaired by a temporally preceding salient distractor, reflecting attentional capture. The visual system, however, can adaptively reduce or even eliminate such a capture effect by endogenously establishing a top-down attentional set. The present study examined whether observers could establish multiple attentional sets to concurrently monitor two different colors. Observers identified a target letter in red or cyan among nontarget letters of other heterogeneous colors presented as a rapid serial visual stream. A distractor frame consisted of peripherally presented four pound signs with one of them in either the same color as the target of the current trial, as the other potential target color, or as an irrelevant color that could never be the target (green). If observers could establish multiple attentional sets to monitor two target colors, attentional capture should be observed only by the distractors of the two potential target colors. If observers cannot establish such bi-color sets and thus use a general set for any colors, the irrelevant color was also expected to capture attention. The results supported the former prediction indicating that observers could establish multiple attentional set for different colors. Subsequent experiments tested whether observers viewing dual rapid visual streams can (a) maintain such attentional control settings, (b) establish two different singleton-detection sets, and (c) establish a singleton-detection and a feature-search set separately for each stream. The results indicated that establishing (a) such two feature-search settings and (c) mixture of sets failed, but (b) two concurrent singleton–detection sets were sustainable during monitoring two streams. Importantly, unexpected but consistent priming effects were obtained, when attempting to establish a feature-search set concurrently with other set. These results suggest that a new framework is required to explain the split of multiple attentional control setting in rapid serial visual presentation.

16.529 **The relationship between attentional disengagement and inhibitory control**

Jennifer Lechak[1](jwi39@wildcats.unh.edu), Andrew Leber[2]; [1]Department of Psychology, University of New Hampshire, [2]Department of Psychology, Ohio State University

It has long been debated exactly how individuals ignore distracting information in their visual environment. One important clue has come from individual differences studies, which have shown that greater working memory capacity (WMC) is linked to resistance to irrelevant distraction. But what is the precise nature of this relationship? Fukuda & Vogel (2011) have argued that greater WMC enables more rapid disengagement from distracting stimuli, suggesting a possible role for inhibitory processing. The present work directly examines this putative relationship between inhibition and resistance to distraction. We ran subjects in 3 tasks: 1) a change detection procedure to estimate WMC, 2) a visual distraction task designed by Fukuda & Vogel to measure the speed of attentional disengagement, and 3) the STOP-IT stop signal procedure, which was designed to measure inhibitory processing (Verbruggen, Logan & Stevens, 2008). Results demonstrated that WMC was negatively correlated with stop signal reaction times (SSRTs); that is, individuals with lower WMC took longer to inhibit the execution of a prepared response. We also found a significant positive correlation between SSRTs and attentional disengagement; specifically, individuals who were slower to implement response inhibition were also slower to disengage from irrelevant distraction. Taken together, these results demonstrate that a previously established measure of inhibitory processing is linked to attentional disengagement, suggesting an important role for inhibition in the efficient handling of visually distracting information.

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16.530 **Understanding peripheral interference: the effects of distractor relevance and eccentricity on capture**

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When an observer monitors a stream of possible targets at fixation, a peripheral distractor can capture attention under some circumstances. Previous research has shown that a distractor sharing the defining feature of the target is more likely to capture attention than one that does not, an effect known as contingent capture (e.g., Folk, Leber, & Egeth, 2002). This has often been attributed to, and taken as evidence that, the operation of feature-based attention occurs in parallel across the visual field, despite knowledge that the target will be at fixation. The current experiments test the validity of this perspective by exploring the spatial specificity of this effect. In these tasks, observers viewed an RSVP stream at fixation (10 letters/s) and reported the identity of a target letter that was defined by a specific color. On some trials, a peripheral distractor appeared 200 or 500 ms before the appearance of the central target. In the contingent condition, the distractor possessed the target color, while in the noncontingent condition it did not. Critically, the eccentricity of this peripheral distractor was manipulated. Attentional capture is quantified as failure to report the identity of the target letter in the central stream. Experiment 1 tested the magnitude of attentional capture at a range of distractor eccentricities (1°, 1.5°, 2.5°, or 4.5°). Noncontingent distractors showed no attentional capture, regardless of eccentricity. Notably, attentional capture in the contingent condition was reduced as distractor eccentricity increased across this range of parafoveal eccentricities. This effect can be attributed to an inhomogeneity in the bottom-up color signal available in the periphery, or it may reflect an interaction between feature-based attention and the distribution of spatial attention during the task. In Experiment 2, we manipulated the amount of attentional focus required to do the central task and found evidence suggesting the latter hypothesis.

16.531 **Dual-target contingent attentional capture effects are modulated by associative learning**

Katherine Moore[1](katherine.moore@elmhurst.edu), Elizabeth Wiemers[1], Somin Lee[2], Celine Santos[1]; [1]Department of Psychology, Elmhurst College, [2]Department of Psychology, Yale University

We recently demonstrated that contingent attentional capture costs are doubled or tripled under certain conditions when participants maintain more than one goal at a time (Moore & Weissman, 2010, 2011). Specifically, such "set-specific capture" occurs when participants must switch between multiple concurrent goals in a visual search task. Here, we found that set-specific capture effects are modulated by associative learning training. Participants searched for target letters presented in either of two colors (e.g. "orange" or "green") in a central rapid serial visual presentation stream, while ignoring distractors in the periphery. On same-set trials, a target-colored peripheral distractor appeared just prior to the central target of the same color. On set-switch trials, the peripheral distractor was a different target color (e.g. green) than the subsequent target (e.g. orange). Half of participants were trained to expect mostly same-set trials, and half were trained to expect mostly set-switch trials. Across all participants, target-colored distractors of both types impaired performance as compared to a no-distractor condition, replicating contingent attentional capture findings. Also, performance was worse in set-switch trials than same-set trials, replicating set-specific capture findings. Critically, these findings were modulated by training: participants with set-switch training showed greatly reduced (but still present) set-specific capture effects during a post-test phase, whereas those with same-set training showed dramatically increased set-specific capture effects. Thus, participants with set-switch training were able to anticipate a necessary set switch when they saw a target-colored peripheral distractor. Two follow-up experiments demonstrate that the training effect is due primarily to rapid and specific associative learning. Increased ability to task-switch more flexibly plays a lesser role.

16.532 **The attentional effects of single cues and color singletons on visual sensitivity**

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Goal: Objects appearing in the visual periphery can automatically capture attention. Last year (White, Lunau & Carrasco, 2012) we compared the exogenous cueing effects of a single disk and a color singleton (e.g., a red disk among green ones). We found lower contrast thresholds and response times for stimuli adjacent to the single cue's location than at the other side of the screen. In contrast, the singleton did not affect performance. Here we investigated whether this dissociation arose because single cues and color singletons differ in the spatial profile of attention that they evoke. We tested a range of cue-target distances, including the exact location of the cue (rather than just adjacent to it). Methods: Observers discriminated the orientation of a Gabor patch that appeared at one of four isoeccentric locations. The Gabor was preceded (106 ms SOA) by cues, red or green circles. The cues had 16 possible evenly spaced locations isoeccentric with the Gabor. In the single cue condition, one cue appeared alone. In the interleaved singleton cue condition, 16 cue circles appeared simultaneously, but one differed in color from the rest. The cues' colors were isoluminant. Observers were instructed that all the cues were task-irrelevant and uninformative. Results: On single cue trials, accuracy was higher and response times faster for stimuli 0º–45º of polar angle away from the location of the cue, compared to 180º away. The color singleton also significantly modulated performance, but to a lesser degree, and with a relative benefit only at 0º (the exact location of the singleton). Conclusion: The onsets of both a single object and an irrelevant color singleton can enhance sensory signals at the cued location. However, the effect of the single cue is larger in magnitude and spatial extent than that of the singleton.

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16.533 **Cues imprecise in modality and physical appearance influence attentional disengagement and saccade direction**

Timothy Wright[1](timwright@psy.fsu.edu), Walter Boot[1], John Jones[1]; [1]Department of Psychology, College of Arts and Sciences, Florida State University

The top-down and bottom-up factors that result in the capture of an observer's visual attention have been studied extensively. However, also critical to visual processing is the length of time attention remains at a location once it arrives there (i.e., attentional disengagement). Studies that have examined attentional disengagement attribute top-down mechanisms as the primary determinant of disengagement speed (Brockmole & Boot, 2009; Boot & Brockmole, 2010; Blakely, Wright, Boot, Brockmole, 2011). These studies have repeatedly demonstrated that when a fixated but irrelevant item shares a feature with an observer's target disengagement is delayed. In general, these studies have not examined the precision at which the attention sets that determine disengagement time operate. The present experiments examined whether similar but imprecise cues modulate attentional disengagement. Participants searched for a target of a specific color by first saccading away from an irrelevant item at fixation. Irrelevant cues were either dissimilar in modality (Experiment 1) or dissimilar in physical match to the target (Experiment 2). Results showed that irrelevant linguistic cues that differed in modality but shared meaning with the feature (color) presented at fixation had minimal influence on how long attention dwelled at the initial irrelevant object within fixation. However, these modality-imprecise cues did influence where attention was allocated following disengagement, as cues consistent with the distractor increased eye movements to the distractor. On the contrary, fixated features that were similar to the target's color but imprecise in physical match influenced when attention was disengaged, suggesting that attention sets may be categorical in nature. In conclusion, similar but imprecise cues influence both where and when attention is deployed, with linguistic cues influencing where attention is deployed and physical cues influencing the time course of disengagement. These findings extend and support a top-down view of attentional disengagement.

16.534 **The Effect of Distractor Presentation Frequency on Saccade Reaction Times and Curvature**

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In tasks requiring an eye movement to the onset of a target, the appearance of a distractor 300 ms prior to the target produces shorter saccade reaction times (SRT) (Hermens & Walker, 2010; Walker, Kentridge, & Finlay, 1995). Time was a requirement for sufficient processing leading the distractor to act as a temporal warning cue to prepare a saccade. In the current study, we examined whether the frequency of the distractor's appearance accounted for the shorter SRTs with an SOA of 300 ms. Participants were in either the 20% or 80% frequency condition. On distractor present trials, a distractor diamond appeared to the left or right of the target location and remained on when the target circle appeared. The participants' task was to make a saccade to the target. Replicating previous research, we found shorter SRTs for distractor present trials compared to absent trials. However, when examined by distractor presentation frequency, this effect held for the 80% frequency condition, but not for the 20% frequency condition. In addition, SRTs for the distractor present trials in the 80% frequency condition were shorter than those in the 20% frequency condition. These results suggest that with frequent distractor presentation, activation of the distractor on the saccade motor map is short-lived resulting in quicker saccade execution to the target. While the longer SRTs in the 20% condition represent a longer activation and competition between the target and distractor. In addition, saccade curvature curved away from the distractor location on all distractor present types regardless of frequency condition. Therefore, the shorter SRTs represent a shorten activation of the distractor when it occurs frequently, although regardless of distractor frequency, there was suppression of the distractor in oculomotor system represented by saccade curvature away from the distractor.

16.535 **The configuration effect in visual search** Li Jingling[1](jlli@mail.cmu.edu.tw), Chia-Huei Tseng[2,3]; [1]Graduate Institute of Neural and Cognitive Sciences, China Medical University, Taichung, Taiwan, [2]Department of Psychology, The University of Hong Kong, Hong Kong, [3]Department of Psychology, National Taiwan University, Taiwan

Salient items usually capture attention, thus are beneficial to visual search. Our previous work, nevertheless, discovered that a collinear salient column can impair local visual search (Jingling & Tseng, 2012). Our display contains horizontal (or vertical) bars regularly arranged in 21 rows and 27 columns, while one column was filled with orthogonal bars, making this column uniquely salient in the display grouped either in collinear or in non-collinear. Observers' task was to discriminate an oriented black bar locating either on the salient column or on the background. Interestingly, responses were slower for a target overlapping on the salient column than on background if the salient column was collinear, while shorter if non-collinear. The goal of this study is to investigate whether the impairment only occurs when a task-irrelevant column is uniquely salient in a search display. This question is important for understanding how contour integration interacts with salience computation, an area that was little studied. In Experiment 1, we reduced the column salience by replacing the homogeneous search display with alternating collinear/non-collinear columns. Observers still needed longer time to discriminate target orientation when the target overlapped with collinear column than non-collinear column. In Experiment 2, we divided the search display into two regions: collinear and non-collinear columns. The salience was the highest at the regions' border, and less at non-border columns. Observers performed the same search, and their RTs were highest when targets on collinear border bars, then on collinear non-border bars, followed by on non-collinear non-border bars, and shortest on non-collinear border bars. This result suggests that collinear contour per se delays local target search, while its spatial uniqueness and boarder location could further slow down target search. This observation is consistent with the neuronal properties in V1, which we speculated a possible site for this interaction.

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16.536 **Internally Generated Simulations of Success and Failure Orient Visual Attention** Alison Chasteen[1](chasteen@psych.utoronto.ca), Penelope Lockwood[1], Nicole White[1], Jay Pratt[1], Davood Gozli[1]; [1]Department of Psychology, University of Toronto

Recent research has found that spatial mechanisms of action-perception processes contribute to concept formation through simulation, such that conceptual processes can affect perceptual processes (Barsalou, 2003). While the effects of simulation on perception have been found with concrete (Estes et al., 2008) and metaphorical (Gozli et al., in press) conceptual words, the present research focuses on the contribution of spatial mechanisms to internal representation of other people. To accomplish this, participants were given three short stories containing two protagonists, one of whom was doing very well and another that was struggling. In the first experiment, each story was followed by a visual discrimination task in which one of four cue names appeared at fixation (the positive protagonist, the negative protagonist, and two new names) followed by a target (X or O) that appeared either above or below the name. Participants identified the target letter as quickly as possible with a keypress when the cue name was one that occurred in the previous story. Consistent with a simulation account, processing names interfered with target processing at the metaphorically compatible location (e.g., target appeared above following the positive name at fixation). In the second experiment, after each of the stories, one the four names appeared either above or below the fixation point and participants were asked to determine if the name had been used in the previous story as quickly as possible. As predicted by simulation, positive names were responded to more quickly when presented in upper space with negative names faster in lower space. The findings of these experiments show that internally-generated simulations of other people who are associated with success or failure recruits mechanisms of visual-spatial attention. This study provides striking further evidence for the strong connections between conceptual processes and the mechanisms of action-perception.

Acknowledgement: Natural Sciences and Engineering Research Council

Face perception: Holistic and parts

Friday, May 10, 5:30 - 8:00 pm

Poster Session, Vista Ballroom

16.537 **Lunari Face Expertise: Holistic processing depends on experience with diagnostic parts** Kao-Wei Chua[1](kaochua@gmail.com), Isabel Gauthier[1]; [1]Vanderbilt University

One kind of perceptual expertise results in holistic processing, the tendency to process objects as entire wholes rather than through constituent features. People who process faces more holistically are better at face recognition (Richler et al., 2011; DeGutis et al., 2013) and individuation, or learning the names of specific exemplars in a category, leads to holistic processing for novel objects (Wong et al., 2008). However, it is unclear how individuation leads to holistic processing. We ask whether improvements in face discrimination are necessarily accompanied by increases in holistic processing, in particular when participants learn through experience that a particular part contains little or no diagnostic information. We developed a training regimen wherein participants learned to individuate faces of a novel race, the Lunaris. One group of participants individuated faces where both face halves were diagnostic (Whole group, N=51). Another group individuated faces where diagnostic information was either only in the top or only in the bottom face half (Parts Group, N=49). Both groups showed improvements in discriminating new Lunari faces of the kind they trained with. Holistic processing of transfer Lunari faces was tested with the composite task (Richler et al., 2011). The Whole group processed new Lunaris more holistically than the Parts group, $F(1,91) = 4.41$, $p = 0.038$. Interestingly, the Parts group showed a pattern of results similar that of individuals with autism (Gauthier et al., 2009), with sensitivity to irrelevant information of the same magnitude regardless of the configuration of parts. Thus, individuation alone does not guarantee holistic processing: attention to diagnostic face parts is more critical. Our results help understand the mechanisms behind the acquisition of holistic processing, and offer a possible explanation for reduced holistic processing in individuals with autism, who have been shown to attend to the mouth (Klin et al., 2002).

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16.538 **Adaptation aftereffect from faces using the bubbles technique** Hong Xu[1](xuhong@ntu.edu.sg), Chengwen Luo[1], Qingyun Wang[1], Philippe Schyns[2], Frederick Kingdom[3]; [1]Division of Psychology, Nanyang Technological University, Singapore, [2]Department of Psychology, University of Glasgow, UK, [3]McGill Vision Research, Department of Ophthalmology, McGill University, Canada

Visual adaptation is a powerful tool for understanding perception. Most studies have focused on the effects of adaptation on low-level features such as local orientation, as in the tilt aftereffect. Adaptation to faces on the other hand can produce significant aftereffects in identity, expression, and ethnicity etc, which are high-level traits. Our recent findings on curve adaptation suggest that the curvature aftereffect can be generated by an incomplete curve (Xu and Liu, VSS 2011), suggesting that missing information about the curve is filled-in. In the current study, we aim to investigate whether aftereffects can be generated by partially visible faces. We first generated partially visible faces using the bubbles technique, in which the face is seen through randomly-positioned circular apertures, and tested whether subjects were able to identify the facial expression through the bubbles. We then selected 9 faces whose facial expressions the subjects could not clearly identify. When we adapted the subjects to a static display such that each trial one of these 9 faces was randomly selected for adaptation, we did not find significant facial expression aftereffect. However, when we changed the adapting pattern to a dynamic video display of these faces, we found a significant facial expression aftereffect. In both conditions, subjects cannot tell facial expression from individual faces. It therefore suggests that our vision system can integrate these unrecognizable faces over a short period of time and this integrated percept will affect our judgment on subsequently presented faces. We conclude that face aftereffects can be generated by partial face features with little facial expression cue, implying that our cognitive system fills-in the missing parts during adaptation.

Acknowledgement: MOE AcRF Tier 1

16.539 **The nature of 5-year-old children's holistic face processing: Evidence from eye-gaze contingency** Goedele Van Belle[1](goedele.vanbelle@uclouvain.be), Jutta Billino[2], Bruno Rossion[1], Gudrun Schwarzer[2]; [1]Face Categorisation Lab, University of Louvain, Belgium, [2]Department of Developmental Psychology, University of Giessen, Germany

Holistic processing of faces, the perception of facial parts as an integrated whole, is considered to be fundamental in adult face processing. Developmental studies suggest holistic processing to be already mature in 4-year-olds (de Heering, et al., 2007) and perhaps even in infants (Cashon & Cohen, 2001; Schwarzer et al., 2007). However, previous studies mainly investigated whether the position/context of single parts/face halves influences the perception of other parts/halves so that the current developmental evidence of holistic processing is rather indirect. Here we addressed this question by means of an eye-gaze contingency approach applied to face perception by Van Belle et al. (2010). Using a gaze-contingent window, we revealed only the fixated part of the face at a time, implying part based processing, while a mask forced participants to process the whole face by gaze-contingently occluding their fixated parts. We tested 25 5 years old children and 19 adults. In each trial, brief presentation of a target face was followed by the target and a distractor face, presented side-by-side and covered by a window or mask, or in full view. Participants had to indicate the target face. Despite an overall lower performance for children than adults, their performance pattern was very similar, with the highest accuracy in full view, and the lowest with the window (part-based) (adults: full=.97, mask= .94, window=.88; children: full=.84; mask=.79, window=.64) and similar results for correct RTs (adults: full=1148ms, mask=1291ms, window=2031ms; children: full=3279ms, mask=4718ms, window=6531ms). Overall, both mask and window decreased performance more for children than for adults suggesting that children's face representation is less robust to reduced diagnostic information. However, in accuracy at least, the slight decrease of performance in the critical mask condition compared to full view did not differ between adults and children, suggesting mature holistic processing at 5 years of age.

16.540 Facial motion facilitates featural, not holistic, processing in children, adolescents, and adults

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Although most of the faces we encounter daily are dynamically moving ones, much of what we know about face processing and its development is based on studies using static faces. Here we report studies with children (8-year-olds), adolescents (12-year-olds), and adults (18- to 20-year-olds) to examine the effects of elastic and rigid motion developmentally. In particular, we used the face composite effect to measure the influence of these classes of movement on face featural versus holistic processing. In the elastic motion studies, participants were first familiarized with a front view of a face chewing and blinking, followed by a static composite face. Participants decided whether the top half of the familiarized and composite faces were the same person. In the static condition, the dynamic familiarization face was replaced with a single static face picture, which was extracted from the dynamic face video. The results showed that, in adults, the composite effect in the dynamic condition was significantly smaller than that in the static condition. This result indicates that elastic facial movement facilitates featural face processing. A comparable motion facilitation effect was also observed in the adolescent group, but not in children. In the rigid motion studies, the same procedure as in the elastic motion studies was used, except that the dynamic face stimuli were faces turning from side to side. We found that rigid motion facilitates featural face processing in adults, adolescents, and children. The results taken together suggest that the ability to utilize rigid motion to optimize face processing is present by 8 years of age, whereas the ability to use elastic facial movement to optimize face processing emerges after 8 years. These findings point to the importance of using more naturalistic dynamic face stimuli to study face processing and its development.

16.541 Contrast negation supports the importance of the eye region for holistic representations of facial identity

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Reversing the luminance values of a face (contrast negation) is known to disrupt recognition. However, the effects of contrast negation are attenuated in chimeric images, in which the eye region is returned to positive contrast (Gilad, Meng and Sinha, 2009). Here, we describe 4 experiments probing the importance of the eye region for the representation of facial identity. In Experiment 1, we asked whether the chimeric benefit is specific to the eye region. Our results show that chimeric faces in which only the forehead, nose or mouth regions are returned to positive contrast do not significantly improve recognition. In Experiment 2, we confirm that positive contrast eyes alone are not sufficient for the improved face recognition of chimeric images. Rather, it is the integration of information from the positive contrast eye region and the surrounding negative contrast face that is essential for the chimeric benefit. In Experiment 3, we demonstrate that the chimeric benefit is dependent on a holistic representation of the facial features. Finally, in Experiment 4, we show that the positive contrast eye region needs to match the identity of the negative contrast region of the image for the chimeric benefit to occur. Together, these results show the importance of the eye region for holistic representations of facial identity.

16.542 Global processing of Navon stimuli primes the general (face) congruency effect but not the standard composite face effect

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Navon hierarchical letter stimuli are often used to measure interference between global and local visual information, with global-to-local interference effects being usually interpreted as evidence for perceptual grouping (e.g., Behrmann & Kimchi, 2003). The relationship between this measure and holistic/configural face perception, namely the encoding of the multiple features of a face as a whole representation, remains elusive. In a recent study, Gao and colleagues (2011) showed that global processing of Navon stimuli increased the sensitivity to incongruence between the upper and the lower halves of a composite face and concluded that global processing of Navon stimuli augments holistic face processing. However, rather than using a standard composite face matching paradigm, the authors used a congruency paradigm with composite faces (e.g., Richler et al., 2008), namely a paradigm that has a built-in decisional confound and includes responses on 'different' trials likely reflecting part-based judgments (Rossion, in press). Here we reanalyzed Gao et al. (2011)'s data by examining only the 'same' trials, as in a standard composite face measure, and found that global processing of Navon stimuli did not increase the composite face effect, neither in accuracy rates nor in correct RTs. The effect initially described is due only to a priming of the 'different' composite face trials, reflecting part-based judgments. These findings reinforce the view that the congruency paradigm with composite faces measures general processes that should not be mistaken with face-specific holistic/configural perceptual processes measured in the standard composite face paradigm. More generally and importantly, they support the view that processing global aspects of hierarchical Navon stimuli is functionally distinct than holistic/configural perception of individual faces (Busigny & Rossion, 2011) and suggest that correlations between the two measures across individuals or impairments at the Navon task in cases of congenital prosopagnosia (Behrmann et al., 2005) essentially reflects general visual processes.

16.543 Evidence for Holistic Facial Expression Processing with a Neurocomputational Model

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Holistic face processing in humans has been studied with regard to identity and emotional facial expressions (Calder et al., 2000). However, prior work on holistic processing of facial expressions has used the partial composite paradigm, which is known to exhibit bias effects (Richler, et al., 2011).The complete composite paradigm (Gauthier & Bukach, 2007) provides a bias-proof way to quantitatively measure the interaction between a subject's or model's decision on whether a cued half remains the same between a pair of composite faces, and the presence or absence of a change in the half of the face that is not focused on in a trial; such an interaction, a congruency effect, is indicative of holistic processing. We performed a series of simulations of the complete composite paradigm with EMPATH, a neurocomputational model of facial expression recognition, in order to predict human behavior in this task. The version of EMPATH that we used has a layer of Gabor filtering corresponding to V1, followed by a layer of Principal Components Analysis corresponding to category specific areas of IT, and finally a perceptron with a hidden layer of units corresponding to PFC (Dailey et al., 2002). We observed a reduction in the holistic facial expression processing effects when the face halves are misaligned relative to when the face halves are aligned as expected with the complete composite paradigm. Our model also performed qualitatively similar to the participants in recent experiments in facial recognition in humans (Tanaka et al., 2011) in terms of accuracy as well as a measure of confidence that we defined for comparison with the reaction times of the participants. Our results suggest that facial expression processing is holistic, using an unbiased test of holistic processing.

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16.544 Are Holistic and Configural Processing Distict? A Within-Subjects Comparison of Four Common Face Processing Tasks.

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Are configural and holistic face processing distinct? There is a lack of consistency in terms and definitions across the literature, and it is not clear whether and how these processing types are distinct from one another. One way to investigate this is to examine patterns of performance across face recognition tasks that are thought to tap into one or the other processing type. For instance, performance patterns on the part-whole task and the composite face task are both thought to reflect holistic processing, so performance on them would be expected to positively correlate. Similarly, the face inversion effect and the configural/featural effect are both thought to arise due to eliciting deficits in configural processing, so performance patterns in these two tasks would be expected to correlate. To examine whether this pattern of correlations exist, we compared performance within-subjects (N=70) across these four commonly-used face perception tasks: face inversion, part-whole, composite face, and configural/featural. Performance data were calculated in terms of reaction time, accuracy, and efficiency scores (the sum of normalized accuracy and reaction time measures). This was done to address the fact that the various tasks might express their effects in terms of RT, accuracy, or some mixture of the two. Results revealed that performance data from the conditions within a given task are strongly correlated with each other. However, there was no evidence of correlations between different tasks that might suggest that they tap into the same mechanisms. A preliminary PCA analysis suggested a similar result, with one factor emerging for each task, and the four conditions within each task loading strongly onto that factor only. Thus, our data suggest that each of these four tasks measures a distinct face processing capacity, rather than tapping into common holistic or configural mechanisms.

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16.545 Holistic and analytic processing of emotional expression in composite faces depends on the combination of expressions

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There are conflicting findings in the literature as to whether facial expressions are perceived holistically or as a mixture of holistic and analytic processes. Here, we further investigated holistic and analytic recognition of facial emotion using composite faces constructed such that the top and bottom halves showed congruent expressions (e.g., fear top, fear bottom) or incongruent expressions (e.g., fear top, disgust bottom). Misaligned versions were created by shifting the lower half of the face until the nose in the bottom half was below the left ear in the top half. In the first two experiments, participants identified the expression cued in the top or bottom half of a face. The target region was alternated across four, 64-trial blocks in which congruency, alignment and expression were within-subjects factors. In Experiment 1, we found that alignment impaired the recognition of disgust in the bottom half when combined with fear in the top half. In contrast, in the same pairing, recognition of fear in the top half was not impaired by alignment. In Experiment 2, alignment impaired recognition of fear (top half) when combined with happiness. Recognition of happiness (bottom half) was impaired in the misaligned condition. Alignment had no effect on recognition of the top or bottom halves of congruent expressions in either experiment. In Experiment 3, participants rated the aligned top-half fear and bottom-half disgust faces as similar to congruent fear faces. The aligned top-half fear and bottom-half happy faces were rated as equally happy as congruent happy faces. Overall, these results suggest that depending on the emotions, facial expressions are perceived both holistically and analytically. When the holistic impression of expressions conflicts with local expression information, interference effects result. In the absence of conflict, expression recognition can proceed in a parts-based, analytic manner with little influence from holistic information.

Acknowledgement: Department of Psychology, University of Otago

16.546 The fate of holistic face representations in long-term memory

Bonnie Heptonstall[1](bonniehe@uvic.ca), James Tanaka[1], Michael Hoven[2]; [1]Department of Psychology, University of Victoria, [2]Maastricht University

Although evidence for holistic face processing has been well established in perceptual and immediate memory paradigms, less is known about the time course of holistic representations over longer retention intervals. In the current study, we examined the fate of holistic face memories in long term memory. In the learning phase of the experiment, participants were trained to identify 12 novel faces (six male, six female) by name (e.g., "Joe") to a criterion of 100 percent accuracy. Next, memory for the eyes, nose and mouth parts of the faces was assessed using a part-whole recognition task. In this task, participants were asked to discriminate a given target face part (e.g., Joe's nose) from its foil presented in isolation and in the whole face. Part-whole recognition was tested for upright and inverted faces either immediately (Time 1 group), seven days (Time 2 group), or 14 days (Time 3 group) after training. The main finding was that the Time 1, 2 and 3 groups demonstrated a significant whole face advantage for parts in upright faces. The pattern of holistic recognition differed for the eyes, nose and mouth parts. Whereas the nose and mouth parts showed a strong whole face advantage at all three time intervals, the eyes demonstrated a whole face advantage only at the Time 3 test. In contrast to upright faces, recognition of parts in inverted faces showed no whole face advantage at any of the three time intervals. In summary, these results provide strong evidence that recently familiarized faces are retained in long-term memory as holistic representations.

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16.547 The Whole-Part Effect is Modulated by Spatial Cues

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In the Whole-Part Effect (WPE) we are better able to discriminate a face part (e.g., eyes, nose, or mouth) when the part is embedded in a face than when it is presented in isolation. The results of a recent study (Konar, VSS 2011) suggest that the magnitude of the WPE may depend on the presence of uninformative external features (e.g., neck, chin, ears, hair). The current experiments attempted to replicate this effect, and to determine if the WPE is correlated with the face inversion effect. A same-different task was used to measure the discriminability of eyes, noses, or mouths presented in isolation or within an uninformative facial context that did or did not include external features. In Experiment 1, the target part was indicated by a word cue ("eyes," "nose," or "mouth") that appeared at the top of the response screen on each trial. In Experiments 2 and 3, the cue was a word plus a short horizontal line displayed at the same height as the target part. Experiment 1 failed to find a significant WPE: response accuracy was the same for parts presented in isolation or within a full face. However, Experiments 2 and 3 found a significant WPE for upright but not inverted faces. Averaged across experiments, there was a small but significant effect of external face parts: the WPE was slightly larger when the stimuli contained a neck, chin, ears, and hair. Since the external features are uninformative, and the spatial cues are present on each trial, their influence on the WPE was unexpected. Finally, we failed to find a significant correlation between the WPE and the magnitude of the face inversion effect. Overall, our results suggest that the WPE is highly unstable, and suggest a role for spatial attention in modulating the strength of the effect.

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16.548 Predicting Face Recognition Skills in Children from Holistic Face Processing and Eye Tracking

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Prosopagnosia is a socially debilitating disorder; especially for children faced with the task of developing social skills (Dalrymple, Corrow, Duchaine, & Yonas, 2012). Studies examining face recognition in adults have supported the hypothesis that holistic face processing underlies effective face recognition abilities. However, only recently has this hypothesis been directly examined in adults. A recent report by DeGutis, Wilmer, Mercado, & Cohen (2012) found that the relationship between measures of holistic processing and face recognition scores is robust. Understanding the role of holistic processing in the face recognition skills of children may aid in the creation of successful interventions for children with prosopagnosia. The present study examined individual differences in face recognition skills of typically developing children and tested two hypotheses; 1. like adults, children with higher scores of holistic face processing would exhibit better face recognition skills and 2. greater attention to the eye region would benefit face recognition whereas attention to extraneous areas, such as the chin, would inhibit successful face recognition. 75 8-year-old children completed childhood versions of the Cambridge Face Memory Task (Pellicano et al., unpublished; Dalrymple et al., 2012) and child-adapted versions of the part-whole task (Tanaka et al., 1993). Regression-based scores of holistic processing significantly predicted face recognition performance (p=0.007) with higher scores on the part-whole task predicting better CFMT scores. Furthermore, although attention to the eyes did not significantly predict face recognition skills, attention to the chin (p=0.04), forehead (p=0.01), and neck (p=0.001) negatively correlated with face recognition scores. These results suggest that individual differences in holistic processing play a significant role in face recognition for typically developing children. Furthermore, attention to extraneous areas of the face may interfere with this process.

Acknowledgement: Dissertation Fellowship of the University of MN National Eye Institute

16.549 **Featural and Configural Processing Use the Same Spatial Frequencies: A Human Observer vs. Model Observer Comparison**

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Previous work has shown mixed results regarding the role of different spatial frequency (SF) ranges in featural and configural processing of faces. Some studies suggest no special role of any given band for either type of processing, while others suggest that low SFs principally support configural analysis. Here we approach this issue by comparing human performance when making featural and configural discriminations to that of a model observer algorithm doing the same task. We find that human performance, measured in terms of accuracy, peaks at around 10 cycles/face regardless of whether featural or configural manipulations are being detected. We also find that accuracy peaks in the same part of the spectrum regardless of which feature is manipulated (i.e., eyes, nose, or mouth). Conversely, model observer performance, measured in terms of white noise tolerance, peaks at approximately 5 cycles/face, and this value again remains roughly constant regardless of the type of manipulation and feature manipulated. The ratio of the model's noise tolerance to a derived equivalent noise tolerance value for humans peaks around 10 cycles/face, similar to the accuracy data. These results provide evidence that the human performance maxima at 10 cycles/face are not due simply to the physical characteristics of face stimuli, but rather arise due to an interaction between available information and human perceptual processing.

Acknowledgement: NSERC

16.550 **Experience-dependent grouping modulates holistic face perception**

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The mechanisms that integrate facial features into holistic perceptual units are relatively unknown. Evidence suggests that basic perceptual grouping mechanisms can contribute to holistic face perception: holistic processing of face, but not non-face objects, indexed via the composite effect, is significantly reduced when the backgrounds upon which faces are presented are themselves misaligned and colored differently, cues that discourage grouping of face halves into cohesive (object) units (Curby, Goldstein, & Blacker, in press). Notably, grouping of elements into objects is flexible and shaped by experience (Zemel et al., 2002). Thus, if attenuation of holistic face perception by shape and color cues that discourage grouping reflects an impact on the perceived "objecthood" of the face, it should be possible to shape this effect by manipulating observers' experience with these cues. Here we tested this hypothesis using a pre-task, in which participants searched for a target among arrays of dual-colored, misaligned conjoined rectangle pairs (forming irregular octagons) (group-1) or single rectangles (group-2). This pre-exposure to the background shapes was designed to encourage their perception as either a single, dual-colored irregular octagon (facilitating grouping of face parts that later appeared on them) or as two independent rectangles (facilitating the independent perception of face parts appearing on them). Results revealed that holistic face perception was significantly modulated by experience with the background shapes: When appearing on the different colored, misaligned rectangle backgrounds, face parts were perceived more holistically by those who had completed the pre-task encouraging perception of the background as a single octagon, relative to those who had completed the pre-task reinforcing the perception of the background components as independent rectangles. This modulation of holistic perception by grouping cues is surprising given the often assumed impenetrability of holistic face perception, and it provides potential insights into the elusive mechanisms underlying holistic face perception.

16.551 **Probit analysis for multidimensional signal detection: An evaluation and comparison with standard analyses**

Tamaryn Menneer[1](t.menneer@soton.ac.uk), Michael J. Wenger[2], Leslie M. Blaha[3]; [1]University of Southampton, UK, [2]University of Oklahoma, [3]Air Force Research Laboratory

We evaluated and compared two methods of data analysis for studies employing general recognition theory (GRT). GRT is a multidimensional signal detection theory that provides a rigorous framework for assessing and defining configural processing, and has been used to disambiguate between perceptual and decisional effects when perceptual dimensions interact (e.g., Cornes et al., 2011; Richler et al., 2008). The first method (Kadlec & Townsend, 1995; 1999) uses a set of marginal and non-parametric methods to indirectly estimate the configuration of underlying probability models, and the second uses probit regression models to estimate fully-parameterized probability models. The latter have previously been applied to GRT data (DeCarlo, 2003), but have not been evaluated in terms of relative strengths and weaknesses, either alone or in combination with marginal methods. Here, simulated data from known GRT configurations were used to determine the relative frequency of correct and incorrect inferences made by the two types of analysis. The two approaches were largely in agreement, but there were some important and striking differences. The results show that is the marginal methods are very conservative with respect to detecting correlations within perceptual distributions (violations of perceptual independence), while the probit analysis is conservative for detecting differences in sensitivity between pairs of perceptual distributions (violations of perceptual separability). The study suggests ways in which the two approaches may be combined (as sources of converging evidence) to support inferences regarding multidimensional signal detection models.

Saturday Morning Talks

Eye movements: Saccades, pursuit

Saturday, May 11, 8:15 - 9:45 am
Talk Session, Royal Ballroom 1-3
Moderator: Alexander Schütz

21.11, *8:15 am*

Saccadic suppression comprises an active binocular mechanism

Jonas Knöll[1](jonas.knoell@physik.uni-marburg.de), Peter Holl[1], Frank Bremmer[1]; [1]Dept. Neurophysics, Philipps-University Marburg, Germany

Saccadic suppression describes the reduction of sensitivity to luminance contrasts at low spatial frequencies around the time of saccades. It has been suggested that saccadic suppression is an active neural mechanism. Yet, its site is as yet unclear as is the question whether it acts monocularly or binocularly. Passive explanations have also been put forward which typically postulate that saccadic suppression is caused by the eyes' high velocity during saccades. If saccadic suppression had a passive origin or if it involved only monocular brain structures, contrast sensititivty should not depend on the movement of the non-stimulated eye during monocular stimulation. Contrast sensitivty was measured psychophysically in a 2AFC task. Human observers performed saccades in depth to visual targets aligned in front of one of the two eyes. This approach resulted in temporally aligned saccades of different size and velocity for the two eyes. In a given trial, we presented a low spatial frequency gabor-patch with variable luminance contrast monocularly either above or below the horizontal meridian to one of the two eyes. Participants indicated the perceived location of the stimulus. Perceptual data were first sorted by saccade velocity. Psychometric curves were next fitted separately for trials in which the stimulus was presented to the slower or the faster eye. Contrast sensitivities were extracted from these fits. When data were analyzed with respect to the eyes' individual velocity, the sensitivity at a given velocity differed between the faster and slower eye. When analysis was based on the velocity of the faster eye, sensitivities were comparable for both eyes. We conclude that saccadic suppression does not dependent on the physical speed of the eye and must hence rely on an active binocular mechanism

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21.12, *8:30 am*

Remapping of attentionally tracked locations

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We easily keep track of moving objects while our eyes are fixating and this ability is not disrupted even when eye movements drastically change the tracked object's coordinates on our retinas. Here we report evidence that this trans-saccadic tracking relies on pre-saccadic updating of attention that is deployed to the motion path of a tracked object. Observers were instructed to attentionally follow a colored blob that moved in discrete steps around a circular path centered at fixation. While observers fixated or prepared a saccade, we presented brief pulses of coherent motion that probed the allocation of spatial attention at different positions relative to the tracked object. Observers reported the direction of these motion pulses, which appeared randomly at past, current, and future locations of the tracked object. During fixation, attention was predominantly allocated to the current and next location of the tracked object. However, just before a saccade, attention was displaced away from these tracked locations in the direction opposite to the upcoming saccade. These new locations corresponded to retinal locations that the current and the next position of the tracked object would have after the saccade (i.e. their remapped locations). These results support the physiological evidence of remapping for a case of voluntary displacement of attention. They suggest that both the current and the next predicted step of a tracked object are remapped across a saccade.

Acknowledgement: This research was supported by a DFG grant to MS, a Marie Curie IOF (235625) of EU's 7th FP and a DFG Emmy Noether grant (RO 3579/2-1) to MR, an NIH grant (R01 EY016200) to MC, and an ANR grant to PC.

21.13, *8:45 am*

Adaptation of micro-saccades reveals active control during fixation

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When asked to maintain their gaze steady on a given location, humans perform small involuntary eye movements, which include drifts and fixational saccades. It has long been speculated that fixational saccades may contribute to the maintenance of fixation, but direct evidence that these movements are under oculomotor control has remained contradictory. Here we show that these fixational saccades are indeed precisely monitored and controlled. We used saccadic adaptation, an experimental procedure in which the stimulus is shifted during saccades, to expose observers to an altered sensory-motor contingency. We first examined whether target-directed saccades with amplitudes within the microsaccade range (30 arcmin) could be adapted. Subjects were instructed to look at a small dot (3'), which shifted by a fixed amount every time the subject made a saccade toward the target. Repeated exposure to this procedure led to changes (both shortening and lengthening, depending on the intra-saccadic shift direction) in microsaccade amplitude. We then examined whether fixational saccades, the microsaccades that occur during fixation of a stationary marker, are also adaptable. Since the occurrence of fixational saccades is unpredictable, we estimated the direction and amplitude of a fixational saccade during its occurrence and shifted the fixation dot proportionally. Fixational saccades also changed during prolonged exposure to this procedure: the average amplitude of fixational saccades decreased following backward shifts of the fixation marker and increased following forward shifts. These findings show that the success of fixational saccades is linked to the post-saccadic position of the fixation point, so that the motor program of fixational saccades is modified if the fixation point is not at the expected retinal location after the saccade. Thus fixational saccades serve to position the eye with respect to the fixation point and are actively controlled at a minute level of detail.

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21.14, *9:00 am*

Saccadic adaptation induced by a perceptual task

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Saccadic adaptation allows for the gradual compensation of systematic position errors and is traditionally thought to maintain saccadic accuracy despite peripheral changes such as muscle weakness or growth. In the lab it is commonly induced by shifting the target during the saccade. Here we asked whether adaptation can be similarly driven by a mismatch between the requirements of a post-saccadic perceptual task and the saccade landing position. Observers were asked to saccade towards a peripheral letter array. At one particular location in the array they had to perform a letter-discrimination task. In pre- and post-adaptation trials, the central letter in the array had to be discriminated. In adaptation trials, the letter at a fixed eccentric location in the array had to be discriminated, such that saccades had to be shortened or prolonged. In contrast to previous research, only the position of the discrimination-letter within the array changed, while the position of the array itself remained identical. There was a strategic adjustment of saccade amplitudes towards the discrimination-letter within few trials at the beginning of the adaptation and the post-adaptation phase. However there was also a slower, gradual adaptation of saccade amplitudes towards the discrimination-letter over 100 trials during the adaptation and the post-adaptation phase. The magnitude of this adaptation was similar to a classic adaptation paradigm, in which the whole array was shifted during the saccade. Further, we found no adaptation with the same stimulus when observers did not perform the discrimination task, confirming that the requirements of the perceptual task were actually driving the adaptation. We suggest that a perceptual task can modify oculomotor commands by

See page 3 for Abstract Numbering System

generating a top-down error signal in saccade maps just like a bottom-up visual position error. Hence saccadic adaptation not only maintains saccadic accuracy, but also optimizes gaze behavior for the behavioral goal.

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21.15, *9:15 am*

Concurrent manual tracking enhances pursuit eye movements Diederick C. Niehorster[1](dcniehorster@hku.hk), Wilfred W. F. Siu[1], Li Li[1]; [1]Department of Psychology, The University of Hong Kong, Pokfulam, Hong Kong SAR

It has been reported that concurrent manual tracking enhances smooth pursuit of a moving target only when the target movement is predictable. Here we report a study in which such facilitation was found when the target movement was unpredictable. The experiment consisted of two conditions. In the eye-hand condition, participants were asked to use pursuit eye movements to track the movement of a cyan Gaussian target (σ=0.6°) on a computer screen (40°Hx30°V) as its horizontal position was perturbed by the sum of seven harmonically-unrelated sinusoids (0.1-2.19 Hz). In the meantime, they used a high precision mouse to control the horizontal position of a red Gaussian cursor (8° below) to vertically align it with the target. In the eye alone condition, the target and cursor motion recorded in the eye-hand condition were replayed, and participants were asked to only track the target with pursuit eye movements. Across 13 participants, the overall eye tracking performance indicated by the RMS eye position error over the course of a 90-s trial did not differ between the two conditions. However, the frequency-response analysis on smooth pursuit eye movement data with saccades removed showed that the average smooth pursuit gain was significantly higher for the eye-hand than the eye alone condition (Cohen's d=0.61), and the pursuit phase lag decreased significantly for four out of seven input perturbation frequencies. Furthermore, while the average saccade amplitudes and durations did not differ between the two conditions, the number of saccades made per trial in the eye-hand condition (mean±SEs: 215±6) was significantly less than that in the eye alone condition (250±6). We conclude that concurrent manual tracking increases the gain and decreases the phase delay of smooth pursuit, and that this pursuit enhancement by concurrent manual tracking is not specific to predictable target movement but is a fundamental property of eye-hand coordination.

Acknowledgement: Hong Kong Research Grant Council, HKU 7480/10H and PF09-3850

21.16, *9:30 am*

Compensation of heading tuning for eye pursuit in Macaque area VIP: Retinal and extra-retinal contributions Adhira Sunkara[1](sunkara@bcm.edu), Gregory DeAngelis[2], Dora Angelaki[3]; [1]Biomedical Engineering, Washington University in St. Louis, [2]Brain & Cognitive Sciences, University of Rochester, [3]Department of Neuroscience, Baylor College of Medicine

Moving in a 3D environment results in a projected vector field on the retina termed optic flow. For linear translations, this pattern is radially symmetric around a 'Focus of Expansion' (FOE) corresponding to the heading direction. Eye movements introduce rotations which disrupt the FOE, obscuring the true heading. Psychophysical studies show that humans are capable of perceiving their true heading despite pursuit eye movements. Two strategies that the brain can use to recover heading in the presence of rotations include (i) Subtracting extra-retinal velocity signals from optic flow (ii) Using visual information present in retinal cues to separate translation from rotation based on the differences in their flow properties. To evaluate the contributions of each strategy, we introduce rotations to translational flow fields using eye pursuit (real pursuit, RP) or add rotation to the stimulus, simulating eye pursuit during fixation (simulated pursuit, SP). RP and SP produce the same retinal stimulation, but SP lacks extra-retinal signals. Heading stimuli (3D dot cloud) is presented for both conditions while recording extracellularly from macaque ventral intraparietal area (VIP), which has both heading direction tuning and eye pursuit responses. We compared the full tuning curve for translations in the horizontal plane to the tuning during RP/SP. We observe slightly larger shifts in tuning (indicating incomplete compensation) for SP than RP, but much smaller than a purely extra-retinal strategy suggests. This study presents neural evidence in support of a combination of retinal and extra-retinal cues for pursuit compensation. We also observe larger gain fields during RP compared to SP, suggesting that gain fields can encode the presence of eye rotations. These gain fields can potentially be useful for identifying whether the rotation present in retinal cues is a result of eye movements or another source such as head movements, or moving on a curved path.

Perceptual organization: Shapes, objects, neural mechanisms

Saturday, May 11, 8:15 - 9:45 am

Talk Session, Royal Ballroom 4-5

Moderator: James Elder

21.21, *8:15 am*

Integration of orientation and spatial cues in dynamic form analysis Steven Thurman[1](sthurman@ucla.edu), Hongjing Lu[1,2]; [1]Psychology Department, UCLA, [2]Statistics Department, UCLA

Form analysis is fundamental to shape perception and biological motion perception, and is notoriously robust in the face of sparse visual input, such as remote markers located randomly along a shape's boundary (Kellman & Shipley, 1991), or located at body joints to form point-light actors (Johansson, 1973). A few studies have put orientation and spatial cues into conflict for static shape perception (Day & Loffler, 2009; Levi & Klein, 2000), demonstrating sophisticated interactions between these cues for global form analysis. Here we create animations of sparsely-sampled, dynamic objects comprised of oriented Gabor patches to explore the relative contribution of position and orientation cues under varying conditions of spatial and orientation uncertainty. Frame-by-frame, a small number of points (2, 4 or 6) were randomly sampled along the shape of a human walker (leftward, rightward) or a rotating square (CW, CCW). We used a one-frame lifetime random sampling technique (Beintema & Lappe, 2006) and manipulated Gabor orientation to either coincide with the spatially-defined shape (e.g. leftward walker, CW rotation) or represent the shape with opposite dynamics (e.g. rightward walker, CCW rotation). Spatial frequency was varied (.25, .75, 1.25 cyc/deg) to manipulate the reliability of orientation cues, and Gabor extent (size) was varied to manipulate reliability of spatial cues. We found significant interactions whereby spatial cues dominated perception as orientation uncertainty increased and vice versa. We introduce a "weak fusion" probabilistic model that uses Bayesian inference within local modules to estimate object dynamics (e.g. rotation and walking direction) independently from spatial cues ('position labels') or orientation cues. With a single free parameter representing the relative weight of these cues during cue integration, we replicate several important features of the data. These results suggest that form analysis integrates competing position and orientation cues in a simple and statistically near-optimal fashion for perceiving dynamic sampled shapes.

Acknowledgement: NIH grant BCS-0843880 to HL

21.22, *8:30 am*

Effective connectivity in human primary visual cortex predicts inter-individual difference in contextual illusion Chen Song[1,2](chen.song.09@ucl.ac.uk), Sam Schwarzkopf[1,2], Antoine Lutti[1], Baojuan Li[1], Ryota Kanai[2], Geraint Rees[1,2]; [1]Wellcome Trust Centre for Neuroimaging, University College London, [2]Institute of Cognitive Neuroscience, University College London

Visual perception depends strongly on spatial context. A classic example is the tilt illusion where the perceived orientation of a grating differs from its physical orientation when surrounded by a tilted context. Here we show that such contextual modulation of orientation perception exhibits trait-like inter-individual variability and correlates with effective connectivity within V1. We used functional MRI to measure activity in human early retinotopic cortices (V1-V3) and applied Dynamic Causal Modelling (DCM) to estimate effective connectivity between foveal and peripheral regions of retinotopic cortices that responded to the visual field location of a central grating and that of its surrounding context, respectively. When the grating was placed in spatial context compared to in isolation, intrinsic connectivity from peripheral to foveal regions of V1-V3 increased, and so did feedback connectivity between V1-V3, but no change was observed in feedforward connectivity between V1-V3. This suggests that visual context modulates cortical activity through a combination of intrinsic and feedback connections. Critically, inter-individual differences in the magnitude of the tilt illusion correlated specifically with intrinsic connectivity from peripheral to foveal region of V1 and not V2 or V3. Neither feedforward nor feedback connectivity between V1-V3 or activity in V1-V3 predicted the illusion magnitude. We conclude that spatial context modulated orientation perception through V1 intrinsic connections. Our findings reveal the role of effective connectivity in shaping perceptual content and its inter-individual diversity. This important role played by V1 intrinsic connections challenges conventional theories emphasizing feedback modulation in visual consciousness.

21.23, *8:45 am*

A novel method for fMRI analysis: inferring neural mechanisms from voxel tuning Rosemary Cowell[1](rcowell@ucsd.edu), David Huber[1], John Serences[1]; [1]Department of Psychology, University of California San Diego

Recent methods for analyzing fMRI data produce voxel tuning functions (VTFs) that relate the value of a stimulus feature (e.g., orientation) to the intensity of the BOLD signal. Modulation of VTFs has been interpreted as reflecting changes in the shape of the response profile across populations of feature-selective neurons. However, knowing how the shape of a voxel response profile is modified by a change in brain state (e.g., viewing stimuli at low versus high contrast) does not tell us how the response profiles of neurons that contribute to that voxel are modified. Mapping a VTF back to neural tuning functions (NTFs) is an ill-posed inverse problem: there are two unknown distributions (the shape and the response magnitude of underlying NTFs) but only one observed distribution (the BOLD signal across values of the stimulus feature). We tackled this inverse problem by using two BOLD response profiles from two brain states (across which VTF shape is modulated) and solving for modulations in the distributions. We collected BOLD data from V1 in subjects viewing oriented sinusoidal gratings at low and high stimulus contrast. Taking orientation-selective voxel responses at low versus high contrast, we fitted multiple alternative models of the modulation of NTFs (additive shift, multiplicative gain, bandwidth narrowing) assumed to drive the modulation in the VTF. We used parametric bootstrapping to penalize overly flexible models. Although the VTF underwent additive shift from low to high contrast, the best-fitting models of NTF modulation accounting for this shift involved primarily multiplicative gain (in line with electrophysiological evidence). This demonstrates that the method can recover 'ground truth' by making use of the constraints imposed by many voxels across two conditions. The method links monkey neurophysiological data concerning NTFs to human fMRI data on VTFs and should ultimately be applicable in other (non-visual) sensory cortices.

21.24, *9:00 am*

Body-extending object effectors: organization of ventral stream object representations reflects body-object interactions Stefania Bracci[1](stefanie.bracci@gmail.com), Marius Peelen[1]; [1]Center for Mind/Brain Sciences, CIMeC - Trento University

The functional organization of high-order visual cortex is not fully understood. Using fMRI, we provide evidence for a new organizational principle by showing that activity in part of ventral visual cortex reflects the degree to which objects are perceived to physically and functionally extend the body. In 4 studies, we measured the distribution of ventral stream responses evoked by pictures of a wide range of objects. These objects were independently rated on several action-related dimensions used to model evoked neural activity. Additionally, the ratings were used to create a similarity space capturing the similarity of the objects on the action-related dimensions, which allowed us to test for brain regions in which multivoxel activity patterns reflected these similarity spaces. Results revealed a selective overlap between representations of body effectors (e.g., hands, feet, and limbs) and representations of body-extending object effectors (e.g., hammers, combs, and tennis rackets). Multiple regression analysis revealed that the response profile of a region in left lateral occipitotemporal cortex (LOTC) reflected the degree to which objects were rated as extensions of the body. This effect was significantly more pronounced in hand-selective voxels than in body-selective voxels and was not observed for other action-related object dimensions, such as hand priming, hand grasping, and hand-action centrality. Finally, whole-brain representational similarity analysis showed that the similarity of multivoxel object response patterns in left LOTC predicted the perceived similarity in the degree to which objects extend the body. No such relation was found for ratings of other action-related object dimensions. Together, these results reveal a clustering of body and object effector representations, indicating that the organization of object representations in the ventral visual pathway partly reflects how the body interacts with objects. More generally, they provide evidence that action-related object properties influence the functional organization of object representations in the ventral stream.

21.25, *9:15 am*

Figure-ground organization of 3D stimuli Tadamasa Sawada[1](tada.masa.sawada@gmail.com), Zygmunt Pizlo[1]; [1]Department of Psychological Sciences, Purdue University

Regions representing objects are called "figures" while "ground" typically refers to regions representing the background of the objects. An important difference between figures and ground is that the figure always has shape while the ground may not have shape. This difference is particularly obvious with natural 3D scenes. A 3D shape of an object does not change when an observer changes his viewing position or when the object is translated and rotated in the 3D space. This is different with 3D background whose geometry (and thus shape) changes when objects move relative to each other. Ability to see 3D shape as the same regardless of the viewing direction is called shape constancy. Can shape constancy be achieved with 3D empty space? We tested human performance in a shape constancy task with a 3D symmetrical rigid "object" and a 3D asymmetrical rigid empty "space". The subject memorized 3D shapes of two test stimuli in the first display and judged whether either of them was identical with the 3D shape of a response stimulus in the second display. The 3D shape of the response stimulus was rotated in depth by 15, 45 and 75 deg angles. The stimuli were viewed binocularly. In "object" condition, the stimulus was perceived as a 3D "polyhedron". In "space" condition, the stimulus was perceived as a 3D curve surrounding space between two polyhedral objects. The results show that the performance with "object" is substantially better than with "space". When the stimuli are shown in isolation (figure without ground or ground without figure), performance improves, especially in the "space" condition. This means that the visual system has the ability to extract the shape of a 3D rigid space between objects, but when objects are present they draw attention as figures away from ground.

Acknowledgement: NSF, AFOSR

21.26, *9:30 am*

Statistical coding of natural closed contours Ingo Fründ[1](mail@ingofruend.net), James Elder[1]; [1]Centre for Vision Research, York University, Toronto, ON, Canada

We seek to understand the statistical regularities in the bounding contours of natural shapes, and how the human visual system exploits these regularities for perceptual grouping and object recognition. Here we employed a dataset of 391 animal shapes, approximated as equilateral polygons. From this dataset we extracted a set of low-order statistical features, including expected circular variance, skew and kurtosis of angles as well as the circular correlation between neighbouring angles. To measure human selectivity for these features, we developed a method for generating contour metamers that match the natural contours on selected subsets of these features, but which lack all other statistical regularities found in the natural shapes. The main challenge here is the constraint that metamers be simple (non-intersecting) closed contours. To solve this problem, we developed a novel method for constructing and sampling from generative maximum entropy models that satisfy all of these constraints. Psychophysical Methods. In a two-interval task without feedback, observers were asked to distinguish between two fragments of contour, one from an animal shape and one from a metamer. We measured the length of the contour fragment required for threshold performance. Results. Matching the expected variance between animal and metamer shapes raised thresholds for all observers, pointing to human selectivity for angular variance information (variation in curvature). At the same time, an ideal observer using only the expected variance performed much better than humans at discriminating unconstrained metamers and animal shapes, indicating that human encoding of this cue is far from perfect. Interestingly, ideal observer models that also exploit higher-order cues (expected skew, kurtosis, correlation between neighbouring angles) fall short of human performance for discriminating natural shapes from metamers that are matched in angle variance, suggesting that humans rely on more complex global cues for discriminating natural shapes.

Acknowledgement: This work was supported by the German Research Foundation (DFG grant FR 2854/2-1)

Perception and action: Locomotion, interception, wayfinding

Saturday, May 11, 10:45 - 12:30 pm

Talk Session, Royal Ballroom 1-3

Moderator: Jeffrey Saunders

22.11, *10:45 am*

Humans perceive object motion in world coordinates during obstacle avoidance Brett Fajen[1](fajenb@rpi.edu), Melissa Parade[1], Jonathan Matthis[1]; [1]Cognitive Science Department, Rensselaer Polytechnic Institute

When an observer moves through an environment containing another moving object, the local optical motion of the object reflects the relative motion between the observer and the object. However, humans can use self-motion information to recover the component of local optic flow due to object motion alone, allowing them to perceive object motion in world coordinates. What role, if any, does this process play in guiding locomotion in the presence of moving objects? Subjects walked through a virtual environment viewed through a head-mounted display and indicated whether they would pass in front of or behind a moving obstacle that moved on a course to cross their future path. If judgments are based on object motion in world coordinates, then manipulations of perceived self-motion should affect judgments because recovering object motion in world coordinates requires factoring out the influence of self-motion. We manipulated perceived self-motion based on non-visual information by adapting subjects to a ~11° leftward shift of their locomotor trajectory. We then compared judgments on a small percentage of randomly interspersed trials without the lateral shift against judgments on trials from another session in which subjects were not adapted to the lateral shift. Although the relative motion between the subject and the obstacle (and hence the obstacle's local optic flow) was the same in both sets of trials, subjects were less likely to perceive that they could pass in front on trials in which they were adapted to the lateral shift. Because visual information was the same in both sets of trials, the difference between conditions can be attributed to the adaptation effect, which influenced perceived self-motion based on non-visual information. The findings suggest that when observers choose routes around moving obstacles, they rely on a combination of visual and non-visual self-motion information to recover object motion in world coordinates.

Acknowledgement: NIH 1R01EY019317

22.12, *11:00 am*

Visual control of precise foot placement when walking over complex terrain

Jonathan Matthis[1](matthj5@rpi.edu), Sean Barton[1], Brett Fajen[1]; [1]Cognitive Science Department, Rensselaer Polytechnic Institute, NY

Successful locomotion over complex terrain such as a rocky trail requires walkers to place each step on a safe foothold with a high degree of precision while also taking the future terrain into account. In a previous study presented at VSS 2012, subjects walked over a path strewn with virtual obstacles while we manipulated the distance ahead of the observer at which obstacles became visible. We found that two step lengths of visual information about the upcoming terrain was sufficient for subjects to walk with the same level of performance as they do when vision is unconstrained. Analysis of subjects' center of mass motion in the different visibility conditions revealed that two step lengths of visual look-ahead provided subjects with sufficient information to exploit their biomechanical structure as efficiently as they do with full vision. In a new experiment, we recorded the accuracy of stepping behavior as subjects walked over a path of irregularly spaced virtual targets. In various conditions, each target became invisible at some point before the subject landed on it. We found that rendering a target invisible at any point during the step to that target (StepN) had no effect on stepping accuracy, but accuracy degraded dramatically if the target became invisible during the preceding step (StepN-1). This finding provides strong evidence that the visual control of stepping to a target occurs during the ballistic swing phase of the previous step; visual feedback of the target during the step itself is unnecessary. This finding supports and advances the theory developed in the previous study that humans use visual information about the upcoming terrain to configure each step so as to exploit the basic biomechanics of bipedal gait and approximate the level of energetic efficiency achievable when walking over flat, obstacle-free terrain.

Acknowledgement: NIH 1R01EY019317

22.13, *11:15 am*

Optimally adapting heuristics: humans quickly abandon the constant bearing angle strategy

Constantin Rothkopf[1,2](crothkopf@bcs.rochester.edu), Paul Schrater[3]; [1]Institute of Cognitive Science, University of Osnabrueck, [2]Frankfurt Institute for Advanced Studies, [3]University of Minnesota

Animals ranging from dragonflies through teleost fish to humans all intercept moving targets using the same strategy of adjusting their speed so as to hold the angle pointing towards their target constant over time. This constant-bearing-angle strategy has been suggested as a fundamental visuomotor heuristic and as an instance of Darwininan intelligence that overcomes the need for complex and expensive computations involving multiple sources of uncertainty. We consider the task of intercepting a moving ball for which many previous studies have shown that humans use this constant bearing angle strategy. Here we manipulated the observation function in a virtual reality setup so as to change the uncertainty of the ball's position parametrically. Specifically, the contrast of the ball changes as a function of the heading angle towards the ball along the subject's momentary trajectory. Subjects adjusted their interception strategy within an average of 26 trials and were consistently able to catch these balls. To gain insight into the adopted new interception strategy, we setup an approximate optimal control models, which is provided observation function governing the uncertainty in state variables given visual observations. Parameters of this model are based on previous literature. The approach utilizes a Monte Carlo sampling of smooth trajectories of increasing complexity in a low dimensional parameter space. This analyses shows that the ideal actor modifies its trajectories by executing controls that increase information gain, and that these changes mirror human behavior. Thus, we provide evidence that humans quickly abandon the constant bearing angle strategy in favor of more informative action sequences, if this allows catching moving targets more reliably. The constant-bearing-angle-strategy is not an invariant heuristic of Darwinian intelligence as humans employ near-optimal information seeking actions that violate the constant bearing angle strategy, but produce less uncertainty in the interception.

22.14, *11:30 am*

A Dynamical Model of Collective Behavior in Human Crowds

William H. Warren[1](Bill_Warren@brown.edu), Adam W. Kiefer[1], Stéphane Bonneaud[1]; [1]Dept. of Cognitive, Linguistic, & Psychological Sciences, Brown University

The global behavior of human crowds is thought to emerge from local, visually-guided interactions between pedestrians. There are numerous physical and computer models of such collective behavior (Helbing & Molnar, 1995; Moussaid, et al., 2010; Pettré, et al, 2009), but few are based on experimental evidence. We are building an empirical "pedestrian model" of locomotor behavior and using agent-based simulations to test whether local interactions are sufficient to generate characteristic patterns of crowd behavior. We have derived model components for steering to a goal, avoiding obstacles, matching the speed and heading of neighbors, and braking. Here we report new data on human crowds and our attempt to model them using a multi-agent simulation platform. We collected naturalistic data on groups of up to 20 participants walking in several scenarios in an open area (12x20 m). Head positions were tracked using a 16-camera motion capture system (Qualisys, 60 Hz). We present videos of the following scenarios, corresponding head trajectories, and animations of qualitative simulations: (1) In the "Grand Central Station" scenario, 20 participants criss-cross an arena for 3 min, while avoiding 10 obstacles and each other. (2) In the "swarm" scenario, 20 participants randomly veer left and right while staying together as a group for 2 min. (3) In the "counterflow" scenario, two groups pass through each other, yielding spontaneous lane formation. In each case, the global pattern is reproduced with a few model components. The results provide evidence that the global behavior of human crowds is emergent and may be accounted for by local pedestrian interactions. We are pursuing questions such as: What is the strength of the visual coupling between neighbors? Can the model simulate individual trajectories? Is swarming a self-organized behavior? Do coherent swarms form spontaneously or derive from explicit switching between control laws?

Acknowledgement: NIH EY5R01 EY010923

22.15, *11:45 am*

Inferring strategies of maze navigation from the movements of the eye and arm

Min Zhao[1](minzhao@rci.rutgers.edu), Andre G. Marquez[1], Pernille Hemmer[1], Eileen Kowler[1]; [1]Department of Psychology, Rutgers University - New Brunswick

Navigating through a visual maze relies on the strategic use of eye movements to select and identify the route. We studied navigation through novel and familiar mazes that were viewed from above and traversed by a mouse cursor. Mazes (12x12 cells) of varying levels of complexity were randomly generated. The same maze was tested on two consecutive trials (training and test), with the test maze either: (1) identical to the training maze ("forward" condition), (2) identical, but with start and end locations reversed ("backward"), or (3) rotated 180 deg. Learning was found only in the forward condition when the identical sequence of actions was required on training and test trials. Travel times and saccade rates were reduced by 15% in test trials, regardless of maze complexity. There was no improvement in the backward condition, and there was a cost when the test maze was rotated (travel time increased 15%). Eye movements revealed two modes of performance that almost never occurred concurrently: exploration, in which saccades were made to search for the correct path while the mouse was stationary, and guidance, in which saccades guided the mouse along the chosen path. Guidance episodes were highly stereotypical, with the eye executing sequences of saccades along the path, leading the mouse. Exploration was idiosyncratic. Some subjects explored extensively with saccades before beginning to move the mouse. Others alternated between episodes of exploration and guidance. Examination of eye and arm movements during maze navigation show that people are able to devise and carry out complex, multi-faceted strategies that trade-

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off visual exploration against active motor performance. These strategies take into account available visual information, memory for the path, confidence that the correct path has been identified, the estimated cost in time of exploring with the eye or arm, and idiosyncratic tolerance for error.

22.16, *12:00 pm*

Parallel formation of multiple decisions in the visual cortex Pieter Roelfsema[1,2,3](p.roelfsema@nin.knaw.nl), Ariel Zylberberg[1,4], Brian Ouellette[1], Chris De Zeeuw[5,6], Mariano Sigman[4], Jeannette Lorteije[1]; [1]Dept. Vision & Cognition, Netherlands Institute for Neuroscience, [2]Dept. Integrative Neuroscience, Neuroscience Campus Amsterdam, [3]Dept. Psychiatry, AMC, Amsterdam, [4]Lab. Integrative Neuroscience, FCEyN UBA and IFIBA, Buenos Aires, [5]Dept. Cerebeller Coordination and Cognition, Netherlands Institute for Neuroscience

Intelligence relies on the capacity to find appropriate sequences of decisions over large decision hierarchies. We do not know yet how decisions are formed at different levels of a hierarchy at the time-scale of a single action or thought. Here we exploit the association between individual perceptual decisions and patterns of activity in the visual cortex to measure the timing of decisions made at different levels of a decision tree. We trained macaque monkeys to mentally trace a curve through two bifurcation points and presented stochastic evidence at every bifurcation by varying the luminance of the two branches. The animals had to choose the brighter branch at each bifurcation. The stimulus therefore represented an explicit decision tree where the second decision became relevant only after a choice for the first one. We recorded multi-unit activity in primary visual cortex (V1) and area V4, from neurons with receptive fields at different levels of the decision tree. We used reversed correlation to measure the influence of the luminance fluctuations on the animals' choices and found that decisions at both levels formed in parallel. The activity of neurons in V1 and V4 reflected the accumulation of evidence: it was enhanced when their receptive fields fell on the relevant branch with a delay >100ms after the presentation of the stimulus. Remarkably, the time course of this decision making signal was similar for the decisions at both levels and evidence even accumulated for the irrelevant lower level decision. The performance of the monkeys benefitted from their parallel decision making strategy. If the first decision is difficult, it is advantageous to choose the branch with the easier second level decision. Our results, taken together, reveal how parallel evidence accumulation enables animals to optimize complex decisions under uncertainty.

Acknowledgement: The work was supported by an NWO VICI grant awarded to PRR

22.17, *12:15 pm*

Visual adaptation aftereffects to actions are modulated by high-level action interpretations Stephan de la Rosa[1], Stephan Streuber[1], Martin Giese[2], Cristobal Curio[1], Heinrich H. Bülthoff[1,3]; [1]Max Planck Institute for Biological Cybernetics, Tübingen, Germany, [2]Hertie Institute for Clinical Brain Research at Tübingen University, Tübingen, Germany, [3]Korea University, Seoul, South Korea

Action recognition is critical for successful human interaction. Previous research highlighted the importance of the motor system to visual action recognition. Little is known about the visual tuning properties of processes involved in action recognition. Here we examined the visual tuning properties of processes involved in action recognition by means of a behavioral adaptation paradigm. Participants looked at an adaptor image (showing a person hitting or waving) for 4s and subsequently categorized a briefly presented test image as either hitting or waving. The test images were sampled from a video sequence showing a person moving from a hitting to a waving pose. We found the perception of the ambiguous test image to be significantly biased away from the adapted action (action adaptation aftereffect (AAA)). In subsequent experiments we investigated the origin of the AAA. The contrast inversion and mirror flipping of the adaptor image relative to the test images did not abolish the AAA suggesting that local contrastive sensitive units are not solely responsible for the AAA. Similarly the AAA was present when we chose adaptor images that were equated in terms of their emotional content indicating that the AAA is not merely mediated by units sensitive to the emotional content of an action. Moreover presenting words (e.g. "hitting" or "waving") instead of images as adaptors led to the disappearance of the AAA providing evidence that abstract high level linguistic cues about actions alone did not induce the AAA. Finally we changed the action interpretation of the adaptors leaving their physical properties unchanged by means of priming. We found that the priming of the action interpretation of the adaptors modulated the size of the AAA. Im summary these results suggest that mechanisms underlying action recognition are particularly sensitive to the high-level interpretation of an action.

Acknowledgement: This research was supported by the EU Project TANGO (FET-Open grant number: 249858).

Object recognition: Mechanisms

Saturday, May 11, 10:45 - 12:30 pm

Talk Session, Royal Ballroom 4-5

Moderator: Thomas Carlson

22.21, *10:45 am*

Typicality Sharpens Object Representations in Object-Selective Cortex Marius Catalin Iordan[1](mci@stanford.edu), Michelle R. Greene[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

The purpose of categorization is to identify generalizable classes of objects whose members can be treated equivalently. Within a category, however, some exemplars are more representative of that concept than other members of the same category (Rosch 1973, Rosch & Mervis 1975). This typicality effect usually manifests as increased speed of recognition, as well as lower error rates for verifying category membership of the more typical item. Despite these behavioral effects, little is known about how typicality influences the neural representation of objects from the same category. To address this question, we performed an fMRI experiment in which participants were shown color photographs from 128 subordinate-level object categories grouped into 16 basic-level categories (4 species of animals, 4 types of plants, 4 transportation modalities, and 4 classes of musical instruments). Typicality for each subordinate within its basic category was assessed behaviorally. We analyzed neural responses in early visual areas and object-, scene-, and face-selective areas: V1, V2, VP, hV4, LOC, TOS, PPA, RSC, FFA. For each brain area, we computed separate similarity matrices (Kriegeskorte et al. 2008) for the most and least prototypical halves of the category set. In V1, V2, and LOC, the most typical exemplars from a basic category had a more similar representation and were more distinct from prototypes of other basic categories (using a category boundary effect measure) than the least typical exemplars. Furthermore, a subsequent analysis showed that in LOC, but not in early visual areas, the most typical exemplars also correlated better than the least typical with the average response elicited by other exemplars. Our results suggest that neural representation differs for typical and less typical object exemplars. More specifically, typicality may be correlated to neural distance between categories in LOC, with highly typical members maximizing dissimilarity to instances of other categories.

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22.22, *11:00 am*

A curvature-processing network in macaque visual cortex Xiaomin Yue[1,2](xiaomin@nmr.mgh.harvard.edu), Irene Pourladian[1], Shahin Nasr[2], Roger Tootell[2], Leslie Ungerleider[1]; [1]National Institutes of Mental Health, National Institutes of Health, [2]Martinos Center for Biomedical Imaging, MGH

Psychophysical studies have demonstrated a special role for curved (as compared to straight) contours. Physiological recordings have demonstrated a significant percentage of cells tuned to curved edges in V4d of macaques. Recently, human fMRI data demonstrated a segregation of activity elicited by curved vs. rectilinear stimuli, which partially overlaps the organization of face vs. scene driven activity. Based on this evidences, we hypothesized that: 1) curvature processing would be anatomically segregated in macaque visual cortex, perhaps including V4; 2) curvature processing in macaques would be anatomically linked with face processing regions. Functional MRI was acquired in four fixating macaques (4.7T, MION, 1.53 mm voxels), in response to round vs. rectilinear shapes of different types, matched to those used in human fMRI. Stimuli included: 1) images of rounded vs. rectilinear real world objects, 2) computer-generated arrays of 3D shapes (e.g. spheres, or pyramids). These shape-based stimuli included no faces or scenes. The known face-selective cortical areas were localized in independent runs. The results revealed discrete regions that were especially well activated by the curved shapes, in both hemispheres of all animals. One region (posterior curvature region, PCR) was located in the vicinity of the foveal representation of V4, on the anterior portion of the prelunate gyrus. A second region (middle curvature region, MCR) was located ~3.1 cm anterior to PCR within the lower bank of the STS. The third and more weakly activated region (anterior curvature region, ACR) was located near the tip of the anterior temporal lobe. The extent (but not the peaks) in MCR and ACR partially overlapped with known face-selective regions. In further experiments we used the banana filters (a variant of Gabor wavelets specif-

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ically tuned to curvature) to quantify stimulus image curvature. The mean banana filter values significantly correlated with fMRI responses across conditions in PCR, suggesting that PCR processes simple curvature (r=0.79)

22.23, *11:15 am*

Ketamine changes the neural representation of object recognition in early visual cortex. Anouk M. van Loon[1,3](a.m.vanloon@uva.nl), H. Steven Scholte[1], Johannes J. Fahrenfort[2], Bauke van der Velde[3], Philip B. Lirk[4], Nienke C. Vulink[5], Marcus W. Hollmann[4], Victor A. F. Lamme[1,3]; [1]Cognitive Neuroscience Group, Department of Psychology, University of Amsterdam, [2]Department of Psychology, University of Utrecht, [3]Cognitive Science Center Amsterdam, University of Amsterdam, [4]Department of Anesthesiology, Amsterdam Medical Center, University of Amsterdam, [5]Department of Psychiatry, Amsterdam Medcial Center, University of Amsterdam

What does recognition of an object do to its representation in the brain? Previous research demonstrated that recognition alters the spatial patterns of fMRI activation even in early visual cortex (Hsieh et al. 2010). This process is thought to depend on feedback from higher-level areas to early visual areas. In turn, feedback activity is suggested to rely on the NMDA-receptor. To investigate the role of feedback in the effect of recognition, we administered Ketamine, an NMDA-receptor antagonist, or a placebo to participants. Participants viewed Mooney images that were initially unrecognizable and later recognizable and grayscale photo versions of the same images. We used representational dissimilarity matrixes (RDM) to investigate how the spatial patterns of fMRI activation changed with recognition. Preliminary data suggests that when the Mooney images are unrecognizable their representation pattern is more similar compared to when the Mooney images are recognized. In other words: from the neural perspective unrecognizable Mooney images all 'look the same', and different neural representations only arise upon recognition. Our data further indicate that the neural patterns of recognized Mooney images more strongly resemble neural patterns of the photographic images than of same Mooney images when not recognized. This effect was observed both in early visual areas and in object related areas. Ketamine reduced these effects of recognition in early visual areas. The representation pattern of the recognized Mooney images remained more similar and as a result resembled the RDM of the unrecognized Mooney images more than with placebo. This suggests that reduction of feedback by Ketamine counteracts the effect of object recognition in early visual areas, or even that feedback is necessary for recognition to occur.

Acknowledgement: European Research Council

22.24, *11:30 am*

The representation of object parts in the human brain Jiedong Zhang[1](zhangjiedong@gmail.com), Yaoda Xu[1]; [1]Department of Psychology, Harvard University

The human brain is an efficient information processing system that can distinguish and recognize visual objects consisting of a great variety of parts. Although parts contribute significantly to object representation and recognition, our understanding is still incomplete regarding what kinds of parts are extracted and represented in the human brain during visual object processing. Behavioral research has shown that human vision automatically segments objects into parts using contour concavities as boundaries between parts. Using fMRI, here we tested whether such parts are indeed represented in human visual cortex during object processing. We used the image of a mug as our stimulus and generated two kinds of parts. The "natural parts" were generated at shape contour concavity and consisted of the handle of a mug as one part and the body of the mug as the other part; and the "unnatural parts" were generated by placing a cut at the mug body and consisted of the handle plus half of the mug body as one part and the rest of the mug body as the other part. We presented these parts either alone, or together in an intact or a scrambled mug configuration. If natural parts are automatically extracted and represented during visual object processing in the brain, then the neural response pattern of the intact object would be better predicted by combining those from the natural parts than from the unnatural parts. By examining fMRI response patterns and using multi voxel pattern analysis, we indeed obtained this result in lateral occipital complex, a brain region previously shown to process object shapes. This result demonstrates that natural parts are computed and represented spontaneously in the human brain during visual object processing.

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22.25, *11:45 am*

Computing an average over space and time Andrei Gorea[1](andrei.gorea@parisdescartes.fr), Jan delOho Balaguer[2], Vincent de Gardelle[1], Christopher Summerfield[2]; [1]Laboratoire Psychologie de la Perception, Université Paris Descartes & CNRS, Paris, France, [2]Department of Experimental Psychology, Wadham College, Oxford University, UK

How much time does it take to compute the summary statistics of an ensemble of stimuli? Bloch's law stipulates that, within the temporal integration time for detection stimulus duration, T, can be traded for its intensity, I (or Contrast, C), while keeping performance constant. Granted linearity, Bloch's law can be inferred from the C-sensitivity function of temporal frequency, TF (the Temporal Modulation Transfer Function, TMTF) of the system. Here we assess the visual system's temporal integration characteristics for extracting one summary statistic of an ensemble of highly suprathreshold stimuli, specifically their average shape and average size. Using items whose shapes (from circles to squares), or sizes (circles of variable radii) were drawn over space or time from a normal or lognormal distribution, respectively, we measured subjects' sensitivity in discriminating between the averages of two shape- or two size-distributions as a function of (i) the display time (27-800ms) of 2-to-12 circle-square shapes simultaneously displayed over space and (ii) the TF (1.2-38Hz) of 10 sequentially displayed circles at one single location. Both discrimination thresholds were assessed with a 2AFC+staircase procedure. The major two findings are that average-shape extraction is quasi-independent of presentation time and that average-size extraction is almost independent of TF (in both cases provided that the individual items remained visible). For the shape averaging experiment it is also found that performance is independent of the number of items (2-to-12) but decreases as expected with the standard deviation of the distribution from which they were drawn. Taken together the results point to the fact that, at least for the two dimensions studied, average extraction occurs at the detection threshold involving the readout of the same neural population code as for the extraction/identification of one single feature with a decision possibly based on the log likelihood function over the stimulated population.

22.26, *12:00 pm*

Reaction Time for Rapid Object Categorization is Predicted by a Representational Decision-Boundary in Inferior Temporal Cortex (IT) J. Brendan Ritchie[1](britchie@umd.edu), Samir Durvasula[1], Junsheng Ma[1], David A. Tovar[1], Nikolaus Kriegeskorte[2], Thomas Carlson[1]; [1]Department of Psychology, University of Maryland, College Park, [2]MRC Cognition and Brain Sciences Unit, Cambridge, UK

Perception requires the brain to make decisions. Models of the link between stimulus, decision and behavior have been motivated by this fundamental insight. In the present study, we were motivated by the question, how does the brain transform an internal representation of a stimulus into a decision? We report two experiments that show reaction times (RT) for an object categorization task can be predicted from perceptual representations of stimuli. We hypothesized that the boundaries between categories of objects in perceptual representations of stimuli (e.g. animate and inanimate objects) also reflect boundaries for decision-making. This hypothesis predicts that individual object representations closer to the decision-boundary in the perceptual representation will be harder to discriminate, requiring more decision-time. To model RTs for the categorization task, distances of individual exemplar representations from the representational boundary were transformed into "decision-times" using a biologically motivated perceptual decision-model (Gold and Shadlen, 2007), in which decision-times are modeled as the number of iterations for the model to converge on a decision. As a first test of our hypothesis, we reanalyzed the fMRI data of Kriegeskorte et al. (2008). Linear discriminate analysis (LDA) was used to find the boundary between animate and inanimate object exemplar representations in human inferior temporal cortex. In accordance with our hypothesis, we found that model decision-times correlated significantly with behavioral RTs (Spearman's $\rho = .333$; $p < .01$). We next extended these findings to MEG time series data. Here, we found RTs correlated with model decision-times based on neural representations of the stimuli 200ms after stimulus onset (Spearman's $\rho = .696$; $p < .01$). Our results suggest that the process of settling on an internal representation of a stimulus is itself partially constitutive of, rather than prior to, decision-making in perception.

22.27, *12:15 pm*

The Temporal Dynamics of Top-Down Knowledge on Object Category Representations David A. Tovar[1](dtovar@terpmail.umd.edu), Thomas Carlson[1]; [1]Department of Psychology, University of Maryland

Our capacity to recognize familiar objects is mediated by both bottom up sensory information and top-down knowledge. Prior knowledge of the category of a to-be-presented stimulus decreases recognition time, and fMRI studies have shown that anticipation of a stimulus increases brain activity in corresponding category selective regions of human inferior temporal cortex. In the present study, we used magnetoencephalography (MEG) to examine the effect of top-down knowledge on the temporal dynamics of object recognition. Thirty-two participants viewed a set of objects with categorical structure (humans and animals) while their brain activity was recorded with MEG. Participants were asked to categorize the stimuli as "human" or "animal" as quickly and accurately as possible. Prior to stimuli presentation, they were given a cue that would correctly identify object category in 80% of the trials (80/20, cue valid/cue invalid). Pattern analysis was used to decode both "anticipated" stimulus category during the cue period and actual stimulus category during the stimulus period. Behaviorally, we observed higher accuracy ($p<.001$) and lower reaction times ($p<.001$) for validly cued trials. In the stimulus period, we observed higher decoding accuracy for validly cued trials ($p<.001$), and a negative correlation between decoding accuracy and reaction time ($\rho = -.622$; $p<.001$). During the cue period, prior to stimulus onset, we could decode the "anticipated" category, and we also observed a significant negative correlation ($\rho = -.604$; $p<.001$) between decoding performance and future reaction time performance, thus indicating that greater anticipatory neural activity produces faster reaction times. Our general findings show that category expectations activate object brain representations that in turn facilitate perception and behavior. Further analysis suggests that the brain generates an average exemplar of a category during the cue period to prime the category representation.

Saturday Morning Posters

Attention: Features and objects

Saturday, May 11, 8:30 am - 12:30 pm

Poster Session, Royal Ballroom 6-8

23.301 **Shared mechanisms for representing the sides of the visual world and the sides of objects: Evidence from a localization deficit following parietal brain damage.** Zheng Ma[1](zma4@jhu.edu), Jose Nino[2], Jonathan Flombaum[1], Michael McCloskey[2]; [1]Department of Psychological and Brain Sciences, The Johns Hopkins University, [2]Department of Cognitive Science, The Johns Hopkins University

We report results from a single patient, JKI, with extensive right parietal damage, and some left parietal damage. JKI is severely impaired in localizing visual stimuli presented in the left hemifield, perceptually displacing them toward the vertical meridian. For example, a stimulus presented at an eccentricity of 9.8° is typically localized by JKI to an eccentricity of only 1.4° or 2.8°. JKI also shows some impairment in detecting and identifying LVF stimuli, and this impairment increases in severity with stimulus eccentricity. In contrast, detection, identification, and localization of RVF stimuli are virtually intact. We investigated JKI's ability to detect, identify, and localize features within objects. We presented rectangular objects with features (circular or triangular notches) that could appear on the left or right side of the object. When objects were presented in the left hemifield, JKI was impaired in detecting the notch features, identifying their shapes, and localizing them to the right or left side of the object. Holding constant the location of a feature in the visual field, his performance was significantly worse for features on the left side of an object than for those on the right. These results demonstrate an object-based deficit similar to JKI's impairment for whole objects; that is, JKI shows similar impairment in processing features on the left side of an object, and whole LVF stimuli. Remarkably, the object-based impairment was also apparent for object stimuli presented in the otherwise intact RVF. When localizing features within objects in the RVF, JKI made the same type of error as for LVF stimuli: He systematically reported notches on the left side of an object as appearing on the right. These results suggest that shared mechanisms are involved in representing the sides of the visual world and the sides of objects, irrespective of absolute position.

23.302 **Shape-based cueing with central cues improves target identification and localization performance for voluntary and involuntary attention** Weston Pack[1](westonpack@berkeley.edu), Thom Carney[1], Stan Klein[1]; [1]Vision Science, University of California at Berkeley

Feature-based attention has been shown to produce faster reaction times but not to improve accuracy for cues presented at fixation. However, shape-based attention is likely a higher level process and may be more susceptible to central cueing effects. In a 6AFC task, observers identified target numbers among letter distractors across time ranges spanning involuntary and voluntary attention. Two independent types of accuracy measures are investigated: the standard location judgment used in most published research which in this task is not subject to response bias, and an identification judgment. In addition, a multinomial model has been developed as a means of measuring and subtracting out response bias to the cued shape (number). The multinomial model allows investigation into how response processes (perceptual or decisional) such as response bias vary between cueing conditions (valid vs invalid), across attention systems, and between and within subjects over the course of the experiment. A non-informative (17% valid) numeric pre-cue was presented at the central fixation location followed by a circular array of 100% contrast alphanumeric characters (1° x 1°) presented at 7.5° eccentricity. The array contains one target number and 5 distractor letters and is followed by masking letters. Cue to mask onset time was varied from 110 to 350ms. Involuntary attention was examined for trials with less than the length of time required to voluntarily shift attention via an eye movement (~200ms). Intervals longer than this are believed to include involvement of voluntary attention. Across all subjects, involuntary and voluntary capturing of attention via a non-predictive central cue improved response accuracy for identifying the target location and identity. The level of abstraction in shape-based cueing may account for this difference from feature-based attention.

23.303 **Errors and Illusory Conjunctions in Identifying Distal Stimuli** Cynthia M. Henderson[1](chenders@stanford.edu), James L. McClelland[1]; [1]Psychology Department, Stanford University

Examination of certain illusory conjunction (IC) errors may provide insight into the mechanisms of object recognition when multiple stimuli are attended. An IC error occurs when a subject reports a stimulus that was not present but that combines features of target and distractor stimuli. While ICs between nearby stimuli have been frequently studied and may be related to crowding (McClelland & Henderson, 2012), the properties of ICs are less clear in cases where target and distractor stimuli are distant from each other. A series of experiments replicated and extended a representative study (Cohen & Ivry, 1989). Subjects observed a display with two white digits and a colored target and distractor letter. Stimuli were interleaved and horizontally displaced from a central fixation mark. On each trial, subjects reported the identities of the digits and then the identity and color of the target letter. The frequency of ICs was critically related to both mnemonic demands and dual task aspects of the procedure. ICs were less frequent though not eliminated when the target letter was reported first, suggesting that some ICs were related to memory errors from reporting the digits first. However, ICs were eliminated when subjects could entirely ignore the digits, even controlling for accuracy. Interestingly, when digits were attended, the relative placement of digits and letters strongly influenced errors – for example, ICs were greatly reduced when the digits were vertically offset from fixation. When the digits and letters were interleaved horizontally, accuracy was reduced when a digit was present just outside rather than inside a target letter's position relative to fixation (the distractor letter's position had no similar effect). This effect did not occur when subjects ignored the digits. These results suggest that attending to and encoding additional stimuli has a particular and positionally-sensitive effect on errors reporting a target stimulus.

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23.304 **Automatic top-down processes mediate selective attention** Erica E. Wager[2](ewager@email.arizona.edu), Mary A. Peterson[3], Jonathan R. Folstein[4], Paige E. Scalf[1]; [1]Department of Psychology, School of Mind, Brain and Behavior, University of Arizona, [2]Department of Psychology, School of Mind, Brain and Behavior, University of Arizona, [3]Department of Psychology, School of Mind, Brain and Behavior, University of Arizona, [4]Department of Psychology, School of Mind, Brain and Behavior, University of Arizona

Current models of attention (e.g. Reynolds & Heeger, 2009) posit that selection of task-relevant material results because the visual system is biased to better represent task-relevant than task-irrelevant inputs. Such biasing may emerge from "top-down" attentional control and/or "bottom-up" perceptual processing (McMains & Kaster, 2011). In this experiment, we investigate whether automatic perceptual organizational processes mediated by "top-down" feedback may also contribute to attentional selection. In figure-ground segregation the ground is suppressed. Ground suppression is greater when a portion of a familiar versus a novel object is suggested on the groundside of a figure; this suppression is likely mediated by feedback from high-level object representations (Salvagio et al., 2012) that lost the competition for figural status. We assessed whether this top-down suppression affects the efficiency of selective attention using a flanker task (Eriksen & Eriksen, 1974). Flanker displays were preceded by figures with either high suppression grounds (i.e., portions of familiar objects suggested but not perceived on the groundside) or low suppression grounds (SOA=110ms). Critically, flanker display elements were positioned such that the task-relevant element fell on the figure and task-irrelevant elements fell on the ground. If automatic, "top-down" perceptual processes involved in perceptual organization can influence attentional selection, flanking items presented on high suppression grounds will be less well represented and influence task performance less than those presented on low suppression grounds. We found that interference from inconsistent flanker items was indeed lower when they fell on the high suppression (9%) versus low suppression (12%) grounds ($p<.05$). Suppression of task-irrelevant material, then, was modulated by automatic, top-down perceptual processes, traditionally considered to be "outside" of the attentional system. Top-down

automatic processes may indeed contribute to selective attention if they, like top-down attention, alter the relative strength with which task-relevant and task-irrelevant material are represented in the visual system.

Acknowledgement: NSF BCS 0960529 Grant to Mary A. Peterson

23.305 **Multi-featured objects: Parallel and serial access to all features** Amanda E van Lamsweerde[1](avanla1@lsu.edu), Melissa R Beck[1]; [1]Louisiana State University

In this study, we tested the ability to have attentional access to two features of an object in parallel. Participants viewed two study features (20-50ms), simultaneously or sequentially, followed by a single test feature. Equal performance for both presentation types indicates parallel access to both features, while higher accuracy for the sequential presentation indicates serial access (Huang & Pashler, 2007). In our two-dimension condition, participants saw a single colored shape (simultaneous presentation) or a colored square and a black shape sequentially. Performance was better for simultaneous presentation, indicating parallel access to both color and shape. In the simultaneous presentation for the single-dimension conditions, two colors or two shapes were adjoined to resemble a single object or separated to resemble two objects. Regardless of the spatial arrangement, performance was equal in the simultaneous and sequential conditions for two colors, indicating that participants could access two different colors in parallel. However, for two shapes, whether the spatial arrangement was separated or adjoined did influence performance. When the shapes were separated, performance was higher in the sequential condition, indicating serial access to the two shape values. When the shapes were adjoined, performance was equal for simultaneous and sequential presentation, as long as both shapes were presented at test. If a single shape was presented at test, performance was higher for the sequential presentation, suggesting that if adjoined shapes are accessed together during the study presentation, they must also be compared together at test. Our results suggest that features from two dimensions (color and shape) can be accessed in parallel, while two features from the same dimension may need to be accessed sequentially, depending on the feature dimension. Uniting two features that are accessed serially into a unified object may allow the participant to access both features in parallel.

23.306 **Interactions between perception, fixation, and attention determine the endpoint of an action** Mark Schurgin[1](maschurgin@gmail.com), Jonathan Flombaum[1]; [1]Johns Hopkins University

Perception represents the world probabilistically. If memories are approximate markers, where will an observer end an action intended to identify a remembered location? We investigated this question straightforwardly. Participants viewed a target dot, followed by a mask. At test, a mouse cursor appeared, and participants moved the cursor to the remembered center of the initial target dot. So that we could evaluate the location where a response was made relative to the starting point of an action, we manipulated the starting position of the mouse cursor. We found a clear effect of whether the mouse began above or below the true target location: when it began above, the mouse was moved, on average, too far (expansion). And when the mouse began below, it was moved too little (compression). Helping to explain these effects, response distributions were always centered below a target's true position. Thus, observers 'aimed' for the same point —below a target— leading to observed compression and expansion depending on the mouse starting position. We hypothesize that this occurs because observers fixate the remembered location while executing the mouse movement, and because attentional resolution is better below compared to above fixation. Eye tracking experiments explore this hypothesis, as well as experiments with alternative response methods. But readers can confirm for themselves: where do you fixate as you move a mouse to an icon position? Practically, these results are important because many studies use mouse responses to investigate the spatial structure of perception without accounting for the mouse starting point, attentional resolution, or fixation locations. Theoretically, these results identify an interaction between attention, perception and fixation when translating perceptions into actions. Specifically, higher resolution locations, with respect to fixation, act as attractors to an executed action. As a result response distributions become distorted relative to the distributions stored in memory.

23.307 **Tracking Serial Dependence Behind an Occluder** Alina Liberman[1](alinal@berkeley.edu), David Whitney[2]; [1]Helen Wills Neuroscience Institute, UC Berkeley, [2]Dept. of Psychology, UC Berkeley

Stable and continuous perception of objects in the world is impressive given the noisy and constantly changing visual input the brain receives from the retina. Yet, it is still unclear what mechanisms underlie such stable perception. We have previously shown (Fischer, Shankey, and Whitney, VSS, 2011 & Liberman, Fischer, and Whitney, VSS, 2012) that observers experience serial dependence in the perception of orientation as well as object information, an effect that extends up to 15 seconds back in time. Here, we asked whether the purposeful attentional tracking of an object over space can modulate perceptual serial dependence. We presented an oriented Gabor patch that traveled behind an occluder, turned around, and exited out from the same side. Both the Gabor traveling behind the occluder as well as the Gabor exiting out had randomly generated orientations. After the stimulus presentation, subjects adjusted a line's orientation to match the orientation of the exiting Gabor. We used this response to measure the serial dependence of subjects' perception between the entering and exiting Gabors. We found that the reported orientation of the exiting Gabor was pulled toward the orientation of the entering Gabor, and that this effect was increased when the subject was able to track the Gabor's position behind the occluder. This result suggests that serial dependence in orientation perception helps maintain object continuity and identity in the face of discontinuous visibility.

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23.308 **Object-Based Attention Capture is a Determinant of Object Closure Effects** Adam Greenberg[1](agreenb@cmu.edu), Marlene Behrmann[1]; [1]Department of Psychology, Carnegie Mellon University

The conditions under which selective attention is object-based are affected by the perceptual organization of the scene. Previous work has examined perceptually grouped object-based effects as evoked by detection tasks (expt 1 Marino & Scholl, 2005; expts 1-3 Avrahami, 1999) or simple luminance/distance/texture discrimination (expt 2 Marino & Scholl, 2005; expt 4 Avrahami, 1999l; Kramer & Jacobson, 1991). Here, we use flanker compatibility measures (Eriksen & Eriksen, 1974) to quantify object-based selective attention in two contexts: one in which the targets of attention appear within closed object shapes, and another in which the shapes are not closed. In Experiment 1, a vertical rectangle at screen center was flanked by four identical rectangles, 2 to the left and 2 to the right (rectangles condition). An exogenous cue then appeared outside of either end of the central rectangle. A set of 10 target/distracter letters were presented, two letters in each rectangle (one on each end). One of these letters (the target) was colored green (or orange, for half the subjects), the other nine (distracters) were white. Subjects performed a letter discrimination on the target. The central distracter was neutral, congruent, or incongruent with the target; and the flanking distracters were either congruent or incongruent with the target. In the lines condition, the horizontal "connectors" that formed the top/bottom of each rectangle were removed, forming 10 vertical lines. Results showed that flankers only have effects when the target and distracters lie on a contiguous region. In Experiment 2, we removed the exogenous cue from the procedure of Experiment 1, alleviating the object-based capture of attention prior to target onset. There was no difference in compatibility effects as a function of object closure, suggesting that object-based attention capture (promoted by an exogenous cue) is critical to the effect of object closure on selective attention.

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23.309 **When? What? The Effect of Temporal and Identity Uncertainty on Object-Based Attentional Selection** Breana Carter[1](BCarter0812@gwmail.gwu.edu), Sarah Shomstein[1]; [1]George Washington University

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 directly evaluate the role of uncertainty in object-based attention guidance. In a series of experiments, we examine the extent to which different types of uncertainty (temporal and identity), influence object-based attention in the presence of high spatial certainty. 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. The target always appeared in the center of the screen producing high spatial certainty. Temporal uncertainty was manipulated by varying delay between the onset of the display and the target (1000ms and 2000ms) in the uncertain condition and a constant delay (1000ms or 2000ms) in the certain condition. Identity uncertainty was manipulated by either reducing or increasing the target item set. Effect of compatibility was observed for both types of uncertainty, with incompatible flankers interfering to a greater extent. Interestingly, however, object based flanker interference was only observed under conditions of temporal uncertainty. These results strongly suggest that uncertainty is a major determining factor in object-based guidance of attention, with object representations influencing attention

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when uncertainty is high. Additionally, results indicate that not all types of uncertainty contribute equally to object-based guidance of attention, thus providing further constraints on mechanisms of attentional selection.

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23.310 The Influence of Task-Irrelevant Spatial Regularities on Statistical Learning

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Research into statistical and sequence learning has demonstrated that we are sensitive to the statistical properties of events and can learn to approximate the probability of their occurrences. Research has also demonstrated that the spatial properties of an event can influence our perception of its non-spatial features, even if the spatial features are not relevant to the task itself. The goal of the current research was to test whether task-irrelevant spatial features could influence our ability to learn the regularities associated with non-spatial events. Using a computerized version of the children's game 'rock'-'paper'-'scissors' (RPS), undergraduates were instructed in two separate experiments to win as often as possible against a computer that played varying RPS strategies. For each strategy, the computer's plays were either presented with spatial regularity (i.e., 'rock' would always appear on the left, 'paper' in the middle, and 'scissors' on the right) or without spatial regularity (i.e., the items were equally likely to appear in any of the three screen locations). Results showed that, although irrelevant to the task itself, spatial regularities had a moderate influence when learning to play against easy strategies (Experiment 1 and 2a), and a more pronounced influence when learning to play against harder strategies (Experiment 2b). When exposed to harder strategies, we also found that, in addition to improving learning, participants were also able to detect switches in the computer's strategies more readily when spatial regularities were evident. Our results suggest that task-irrelevant spatial features can improve statistical learning, especially when the regularities of task relevant non-spatial features are difficult to learn.

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23.311 Do low-level visual features have a causal influence on gaze during dynamic scene viewing?

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Recent evidence of eye-movement behavior during dynamic scene viewing has shown that low-level visual features such as motion are of greater magnitude and contrast at fixation than at non-fixated locations. However, it is still unclear if the features at fixation are causal in attracting attention or merely correlated with higher-level features such as people. We investigated the influence of motion, edge, and luminance contrast features on eye-movements by either retaining or filtering out each of these features in video clips while participants rated their preference for a 3 second clip. Do participants exhibit the same eye movements and attend to the same locations of a scene when individual or combinations of visual features are removed? Our results suggest that motion and edge information are required for normal eye movement behavior in dynamic scenes. Removing contrast has minimal impact on gaze behavior as measured by gaze entropy, fixation durations, and saccade amplitudes. Removing either edge or motion information significantly increases fixation durations and shortens saccade amplitudes. However, the removal of edge information on its own has a significantly greater impact on fixation durations and saccade amplitudes than the removal of motion. This difference may be due to the fact that removing motion does not impair the initial gaze bias towards human figures observed in the original clips whereas removing edges does. Edge information is required to locate people in a dynamic scene and create typical eye movement behavior. Motion is important for typical timing and amplitude of gaze shifts but not for locating typical focal features such as people. These results suggest that typical gaze behavior in dynamic scenes is due to an interaction between low-level visual features and scene semantics which can be used to compensate for impoverished low-level cues and guide attention to relevant scene content.

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23.312 Influences of Object Properties to Attentional Guidance

Alexander Etz[1](alexetz@gwmail.gwu.edu), Michelle Rattinger[1], Anna Byers[2], Sarah Shomstein[1]; [1]Psychology, George Washington University, [2]Psychology, UC San Diego

Recent studies suggest that target-to-object relationship (whether the target appears to be a part of the object or is perceived as placed on top of an object) is the primary factor that determines whether attentional guidance is influenced by object representations (Chen & Cave, 2006; Richard, Lee, & Vecera, 2008; Hollingworth, Maxcey-Richard, and Vecera, 2012). Others, however, suggest that object-based selection is largely driven by spatial uncertainty of target location (Shomstein & Yantis, 2002; Drummond & Shomstein, 2010). Here, we re-evaluate the contribution of spatial uncertainty to object-based attentional guidance as well as examine the interaction between spatial uncertainty and target-to-object relationship. In a series of five experiments, object-based effects were measured as a function of whether the target location was known in advance (certainty manipulation) and whether the targets were perceived to be as concavities of the object (bites), floating on top of the object (floaties), or part of an object (parts). We observed object-based effects only when target location was uncertain, independent of whether the targets were interpreted as being part of the object (bites), or simply placed on top of the object (floaties). There was an exception, however, with parts failing to elicit object-based effects. These results re-instate the importance of location uncertainty in object-based attentional guidance, and suggest that object representations, placed within the boundaries of an attended object, benefit perceptually regardless of whether they are perceived to be an integral part-of or on-top-of the object.

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23.313 Hierarchical binding in multi-part objects

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Percepts under stressed visual attention (e.g., brief peripheral presentations) contain systematic errors that suggest perceived objects correspond to independently sampled features (Vul & Rich, 2010). Here we investigate the possibility of a hierarchy of binding: are colours free-floating features within a spatial region, or are they associated to some attribute of the objects? To test if object parts are mapped to colour before features are bound to complete objects, we asked subjects to report the two colours of a multi-part object. We examined several object types, such as a bullseye with one central colour and another as the surround, and a cross with differently coloured vertical and horizontal bars. A cued target object was presented in a circular array of similar distractors arranged around fixation. The whole array was briefly presented and participants were asked to report both colours of the target (e.g., the colour of the inner and outer circles). The colours of object parts near the target object were chosen to be unique, so incorrect reports of target letters could be identified as intrusions from a particular part of a particular object. In this task, binding can break down at different levels: features, parts, or objects, each predicting different patterns of error responses. We find that across a large number of object types, binding does appear to be hierarchical. Errors occur as entire misreported objects (10% of the time on average), as object parts with correct binding of colours to substructure (12%), as colour intrusions from adjacent objects (67%), and as guesses (.11%). However, for objects with more complex part arrangements, intrusions of bound sub-parts reduce to zero. Together, these results suggest that the visual system binds features into objects hierarchically and that conscious perception amounts to sampling at a number of different levels of object representation.

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23.314 Neural correlates of tracking an object through feature space

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Humans can flexibly select locations, features, or objects in a scene for prioritized processing. Although it is relatively straightforward to manipulate location- and feature-based attention, it is difficult to isolate object-based selection. A critical problem is that objects are always composed of features. Thus most studies of object-based selection can be explained in terms of selection of a combination of locations and features. Here we aimed to demonstrate a pure case of object-based selection. Subjects viewed two superimposed gratings that continuously changed their color, orientation, and spatial frequency. On each trial, each grating started with a fixed set of features and then continuously evolved along a fixed trajectory in feature space. Over the time of a trial (6 s), the two gratings traversed exactly the same feature values in each dimension, thus were completely equivalent in terms of visual features. Subjects were cued at the beginning of each trial to attend to one or the other grating to detect a brief threshold-level luminance increment. We first trained subjects on the behavioral task to criterion and then measured their brain activity with fMRI during the task. We found a network of occipital and frontoparietal areas active during the tracking task. The mean fMRI response amplitude did not differ across the two attention conditions (attend grating 1 vs. attend grating 2) in all areas. However, using multi-voxel pattern classification, we were able to decode the attended grating in a set of frontoparietal areas, including intraparietal sulcus (IPS), frontal eye field (FEF), and inferior frontal junction (IFJ). Early visual areas exhibited weaker decoding accuracies. Thus, a perceptually varying object can be represented by patterned neural activity in frontoparietal areas. We suggest these areas encode attentional priority for high-level objects independent of their locations and features.

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23.315 **Attention field size effects in transparent motion discrimination** Philipp Schwedhelm[1](pschwed@gwdg.de), Florian Kasten[2], Stefan Treue[1,3]; [1]Cognitive Neuroscience Laboratory, German Primate Center, Goettingen, Germany, [2]Institute of Psychology, University of Hildesheim, Germany, [3]Faculty of Biology, University of Goettingen, Germany

The Normalization Model of Attention (NMoA; Reynolds & Heeger, Neuron 2009) provides a parsimonious explanation for many of the diverse effects of attention on neuronal responses in visual cortex. A core prediction of this model is that the relationship between stimulus size and attention field size determines whether attention has a contrast or response gain influence on neuronal activity. This has since been confirmed for spatial attention, but for feature-based attention Herrmann et al. (Vision Research, 2012) found that regardless of the extent of the attention field within the feature dimension orientation, only response gain effects are observed. They argued that this is explained by the NMoA since it predicts contrast gain effects only for very narrow tuning bandwidths. We tested this prediction in a direction discrimination task, which allowed for an increased ratio between tuning bandwidth and attention field size. Subjects viewed random dot patterns containing two directions in transparent motion and compared these with a subsequent single motion, indicating the direction change relative to the closer direction of the transparent motion stimulus. Using an abstract cue with 75% validity, we directed feature-based attention to ranges of either 20° or 110° width for the target direction. We then varied motion coherences and assessed attentional effects on psychophysical performance. In agreement with Herrmann et al. we find that the feature attention field can be modulated by means of a visual cue, and we have first experimental evidence of such a modulation for attention to visual motion. However, our results indicate a combination of contrast and response gain, to a large degree following predictions made by the NMoA. We conclude that the type of neuronal modulation evoked by feature-based attention depends on the relationship between tuning width for the given feature dimension and the width of the attention field in that dimension.

23.316 **The effects of dyslexia on the spatial and feature-based attentional modulation in the human subcortical visual nuclei.** Scott Munro[1,2](scmunro@yorku.ca), John Patrick Hegarty[3], Keith A. Schneider[2,3,4]; [1]Department of Psychology, York University, [2]Centre for Vision Research, York University, [3]Department of Psychological Sciences, University of Missouri – Columbia, [4]Department of Biology, York University

Introduction: Dyslexia is a prevalent reading disorder. The magnocellular hypothesis of dyslexia suggests that deficits in the magnocellular processing stream may account for some of the symptoms associated with the disorder. In the human lateral geniculate nucleus (LGN), magnocellular neurons are segregated into eye-specific layers and are disjoint from the parvocellular layers. This constitutes the only location in the human visual system where the magnocellular and parvocellular streams are spatially disjoint. Recently we found a reduction of the LGN size in dyslexics compared to IQ matched controls. Here, we functionally examine the modulation of spatial and feature-based attention in the LGN, superior colliculus and pulvinar. Methods: Thirteen dyslexics with measured behavioral deficits and 13 IQ matched controls were scanned with a Siemens Trio 3T MRI scanner at the Brain Imaging Center at the University of Missouri. In separate scanning sessions, the subjects performed detection and discrimination tasks on semi-coherent moving or static colored dot fields that required either spatial and/or feature-based attention. The LGN were anatomically isolated and traced using a series of averaged high-resolution proton density weighted images. The attentional modulation was compared between controls and dyslexics. Results: We observed differences in the spatial and feature-based modulations of attention between the subjects with dyslexia and controls in each subcortical nucleus. We examined the spatial distributions of these effects throughout the LGN and compared the regions of the LGN more activated by attention to motion than to color as well as those regions that were activated or suppressed by attentional switching. We discuss the implications of these results in terms of the magnocellular theory of dyslexia.

23.317 **A retinotopically-based compatibility bias: Task-irrelevant location information influences object identity judgments** Julie Golomb[1](golomb.9@osu.edu), Colin Kupitz[1]; [1]Dept of Psychology, The Ohio State University

To function properly in the world, we need to bind the features and identities of objects with their spatial locations. How automatic is this process, and what is the nature of this location information? Subjects saw two sequentially presented novel “objects” (each presented for 500ms and masked, separated by approximately 1sec memory delay), and were instructed to make a same/different object identity comparison. The task was designed to be challenging, with only subtle changes in shape when identity differed. Importantly, the second stimulus could appear in either the same location as the first, or a different location. Despite being irrelevant to the task, object location influenced behavioral performance in two ways: When the objects appeared in the same location, subjects (1) had faster reaction times, and (2) were significantly more likely to respond “same identity” (i.e., a location-identity compatibility bias). This compatibility bias was substantial, indicating that subjects were unable to suppress the influence of object location, even when it was maladaptive to the task. We next asked: If location is automatically bound to representations of object identity, does it update across eye movements? Subjects performed the same task, but the fixation cross moved during the memory delay, cuing a saccadic eye movement. Thus, the two stimuli could appear in either the same spatiotopic (absolute, screen-centered) location, the same retinotopic (eye-centered) location, or completely different locations. Critically, the location compatibility bias persisted after an eye movement, but only in retinotopic coordinates. In a separate experiment we also found a location compatibility bias for a same/different color task, with the bias remaining predominantly in retinotopic coordinates. The fact that location-identity binding occurs automatically and is anchored in native retinotopic space may have important implications for its utility in object recognition and stability.

23.318 **Perceiving the size of individual objects in ensembles under focused and distributed attention** Maria Bulatova[1](bulatovamaria@yandex.ru), Igor Utochkin[1]; [1]The National Research University ‘Higher School of Economics’, Russia

Representing summary statistics of visual ensembles is an efficient tool to rapidly encode the features of multiple objects at a glance. However, even when “seeing” average, we still perceive numerous distinct objects and are aware of their variation to some degree. What information is still stored about the individuals during ensemble perception? Brady and Alvarez (2011) showed that the stored size of individuals is typically biased to an ensemble average. We attempted to test how ensemble characteristics affect rapid representation of individuals when attention is focused on that individual or distributed across the entire ensembles. Observers were presented with sets of 1 to 16 circles of variable size (4 distinct sizes could be involved in a trial). On the one half trials, the location of an arbitrary chosen circle was precued (focused attention), on the other half trials, the location was postcued (distributed attention). Two test items were presented after the set forcing observers to choose one looking like the cued circle. On a half test pairs, a larger member was correct choice. Correct responses were measured as accuracy index and the probability of choosing a larger member was measured as bias index. We found in the result, that average accuracy was predictably lower in distributed attention condition for all set sizes including 1 item. Accuracy tended to fall down with set size for both focused and distributed attention, however, for distributed attention the fall was more dramatic indicating increasing noisy interactions between individuals. The general bias trend was underestimating the size of individuals. In focused attention condition, this underestimate was slight. In distributed attention, this underestimate trend remarkably increased with an item size. This indicates strong tendency to compress estimated size around smaller values. In this sense, representations of individuals indeed appear to be more averaged in distributed attention.

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23.319 **Visual and auditory object-based attention driven by rhythmic structure over time** Julian De Freitas[1](julian.defreitas@yale.edu), Brandon Liverence[1], Brian Scholl[1]; [1]Department of Psychology, Yale University

Objects often serve as fundamental units of visual attention. Perhaps the most well-known demonstration of object-based attention is the ‘same-object advantage’: when attention is directed to one part of an object, it is easier to shift to another part of the same object than to an equidistant location on a different object. Does this effect apply only to spatial shifts of attention, or can same-object advantages also occur based on purely temporal structure? We explored this question using rhythmic stimuli, composed of repeating "phrases" (of several seconds each), and presented either auditorily or visually. Auditory stimuli consisted of sequences of tones (of a single frequency), temporally arranged to yield regular (and independently normed) rhythms. Visual stimuli consisted of the same rhythms "tapped out" by a moving bar on a computer screen. Subjects detected infrequent high-pitch probe tones in the auditory experiment, or high-luminance probe flashes in the visual experiment. Probes were preceded by temporally-predictive cue tones (or flashes), so that each cue-probe pair either occurred within a single phrase repetition (Within-Phrase) or spanned a phrase boundary (Between-Phrase), with the brute cue-target duration equated. In both modalities, subjects detected Within-Phrase probes faster than Between-Phrase probes - and further control studies confirmed that these effects weren't driven by the absolute probe positions within each phrase. Thus same-object advantages are driven by temporal as well as spatial structure, and in multiple modalities. In this sense, "object-based visuospatial attention" may not require objects, and may not be fundamentally visual or spatial. Rather, it may reflect a broader phenomenon in which attention is constrained by many kinds of perceptual structure (in space or time, in vision or audition).

23.320 **Visual long-term memory for objects biases perceptual attention** Judith E. Fan[1](jefan@princeton.edu), Nicholas B. Turk-Browne[1]; [1]Department of Psychology, Princeton University

How does past experience with an object influence how we deploy attention to it in the future? Although the guidance of attention based upon external salience and internal goals has been studied extensively, the mechanisms that underlie attentional guidance from long-term memory are not as well understood. Here we examine how visual long-term memory for objects influences their selection during visual search. In an initial encoding phase, observers learned to associate unique color and location features with each of several abstract shapes using a continuous report visual short-term memory task. In a subsequent search phase, observers were cued to search for these shapes among cluttered arrays of novel colorful distractors. On each trial, a colorless, centrally presented version of one shape was presented as the cue, and the target in the array (for present trials) appeared in either: the learned color, learned location, both, or neither. Although the color and location features associated with the shape were not relevant to the instructed task of finding the shape in whatever color and location it appeared, detection was quickest when the target appeared in both the color and location that was consistent with visual long-term memory, and slowest when it appeared in a novel color and location. We found intermediate search latencies when only one of these features matched long-term memory, suggesting that attention is guided in an additive manner by memory for different feature dimensions. In ongoing experiments, we are exploring whether long-term memory for objects guides attention via biasing mechanisms in working memory, and whether such retrieval sets up a general priority for associated features that can even influence processing of other objects. Taken together, these investigations contribute to our understanding of how memory systems incidentally and powerfully shape how we attend to and perceive the visual world.

Visual search: Memory, attentional capture

Saturday, May 11, 8:30 am - 12:30 pm

Poster Session, Royal Ballroom 6-8

23.321 **Attention and memory resolution in visual search for hierarchical objects** Markus Conci[1](conci@psy.lmu.de), Qi-Yang Nie[1], Hermann J. Müller[1]; [1]Department of Psychology, Ludwig-Maximilians-University, Munich, Germany

Objects can be represented at multiple hierarchical levels, but typically, more global object levels receive precedence over more local levels. Here, we explored how object hierarchy affects the resolution of attention and memory using a visual search task with Navon letters as global/local targets and non-targets. Our results show that search for targets defined at the global level was more efficient than search for comparable local-level targets. Moreover, this global precedence effect on attention was transferred to memory, as an analysis of cross-trial contingencies revealed priming to occur only for global targets but not for local targets. Subsequent experiments manipulated the prevalence of global and local targets to investigate the stability of this global/local processing asymmetry. When local targets were presented more frequently than global targets (i.e. local targets on 75% of all trials), global precedence was overall reduced and priming occurred at both object levels. In addition, when systematically changing the prevalence of global and local targets throughout the experiment, attention showed a dynamic hierarchical adjustment according to target prevalence. In contrast, memory (priming) was unaffected by changes in target prevalence. In sum, our findings demonstrate that hierarchical object structure is represented beyond mechanisms of perceptual organization, as global precedence affects the resolution of both attention and memory. However, both processes show different underlying dynamics, with transient object-level adjustments occurring in attention but not in memory.

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23.322 **Guidance of Visual Search by Working and Long-Term Memory Representations of Orientation** Mark W. Becker[1](becker54@msu.edu), Chad Peltier[1], Reem Alzahabi[1]; [1]Department of Psychology, Cognition and Cognitive Neuroscience Program, Michigan State University

A number of theories suggest that one can bias visual search toward goal-relevant stimuli by representing a template of the search target in working memory (WM). Recently, Woodman and colleagues used ERP evidence to argue that the search template was handed-off from WM to Long-Term Memory (LTM) when the target remained constant for a number of trials. Here we provide behavioral evidence of this hand-off. Participants' eye movements were monitored as they performed a difficult visual search among oriented bars. Cues indicated the orientation of the bar that would contain the target (if present). Eye movements were biased toward bars of the cued orientation. When the cued orientation remained constant for a block of trials, this bias appeared to be based on a categorical (steep/shallow) representation of the target orientation rather than a visually specific representation. For example, when the cue was +22.5° from horizontal (shallow) the eyes fixated bars that were -22.5°degrees from horizontal (shallow) much more frequently than bars that were -22.5° from vertical (steep), even though both these orientations were 45° from the cued orientation. When cued orientations were randomly interleaved, this categorical bias was greatly reduced (but did not completely disappear), suggesting that the guidance was based on a more precise visual representation. These results provide a potential behavioral marker of the shift from WM to LTM guidance, and suggest that the nature of the representation is different between these two memory systems. The LTM system seems to maintain a more abstract, categorical representation, while the WM system maintains a more specific, visually-based representation.

23.323 **Incidental memory for potential targets vs. confirmed distractors** Corbin A Cunningham[1](cunningham@jhu.edu), Jeremy M Wolfe[2,3], Howard E Egeth[1]; [1]Department of Psychological and Brain Sciences, Johns Hopkins University, [2]Harvard Medical School, [3]Brigham & Women's Hospital

Humans have very extensive recognition memory for pictures of objects. In Brady et al. (2008), observers viewed thousands of objects for 3 seconds each. They reported on items that repeated in the series. Subsequently, they could identify >87% of images as old or new even if "new" items were old items in new poses. In the real world, looking for repeated items is atypical. More commonly, we move through the world, looking for some objects and encountering other, irrelevant objects. How good is memory for these non-target items after we have searched for multiple target items in streams of hundreds of images? Groups of 10 observers memorized 1, 12, or 24 items. They then looked for any of those target items in a stream of 810 objects. 110 targets were present in the stream. Ten additional observers performed a repeat detection task similar to Brady et al. Afterwards, all observers performed the Brady et al. discrimination task. They saw pairs of images and were asked to indicate which item was previously seen. Different comparisons were tested. Previously viewed items could be paired with novel objects, categorically similar objects, or the same objects in different poses (e.g. backpack open or closed?). ANOVAs revealed that search for memorized target items produced worse incidental memory for distractors than did search for repeated items. There was no significant effect of the number of target items held in memory even though it took longer to determine that an item was not a member of a larger memory set. This effect was larger for the novel comparison than the state comparison. In the repeat detection task, every item could be a target. This produced better memory for non-targets than a task where non-targets are not task-relevant, even though all items must be processed in both cases.

23.324 **Implicitly guided attention is immune to visual working memory load** Bo-Yeong Won[1](wonxx039@umn.edu), Yuhong Jiang[1]; [1]Department of Psychology, University of Minnesota

Debates about spatial attention often center on its nature (e.g., one or multiple foci) rather than its heterogeneity (e.g., one or multiple types). Many studies have demonstrated that spatial attention is involved in visual search, visual working memory, and is modulated by perceptual salience,

goals, and implicit learning. Yet it is unclear whether the same system is involved in these tasks and processes. To better understand the fractionation of spatial attention, we examined the influence of visual working memory on implicitly learned attention. If the same type of spatial attention underlies spatial working memory and implicit learning, then increasing working memory load should interfere with implicitly guided attention. In three experiments, participants remembered a color array or dot locations in working memory. During the memory retention interval, they conducted a visual search task for a T target among L distractors. Unbeknownst to the participants, the T was more often found in certain locations than others. When working memory load was low, participants were faster finding the target when it was in the high-probability locations than low-probability locations, and this enhancement scaled with set size. Increasing working memory load delayed search RT. However, location probability learning was equally robust under high and low working memory load. In addition, learning acquired under low load transferred to search under high load, and vice versa. These findings indicate that the type of spatial attention involved in visual working memory is not crucial for location probability learning. Additional experiments showed that although probability cuing was insensitive to working memory load, it was task specific. We suggest that spatial attention is comprised of a "where" and a "how" system. Goal-driven attention affects where attention should be deployed, but implicit learning modulates how attention is allocated in a task.

23.325 The role of the parietal cortex in feature binding in visual search

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The ability to combine simple visual features in the environment to distinguish individual objects is an essential aspect of visual perception. This process, called feature binding, has previously been described as a mapping of multiple features to a location in space (Treisman, 2006). Areas of the parietal cortex have been shown to have specificity for different forms of visual attention related to stimulus processing. In particular, dorsal parietal attention areas contain retinotopic maps for spatial attention, while ventral parietal attention areas are lateralized to the right hemisphere and have not been shown to have this kind of location specificity in their responses. Evidence from both patient and TMS studies suggests a role for the parietal cortex in feature binding. Using a within-subject fMRI design, we compared cortical regions involved in two types of visual search. Subjects detected a target defined by a single feature (color pop-out search) on some trials, while on other trials the target was defined by a conjunction of two features (color-shape conjunction search). Task difficulty was matched for the two types of search by manipulating stimulus-mask onset asynchrony. We used retinotopic mapping to define early visual and dorsal parietal (IPS0-5) areas and found that parietal cortical activity distinguished between feature and conjunction search only in areas outside of the topographically-organized dorsal attention network. This activity was consistently centered within the anatomically-defined angular gyrus and was predominantly in the right hemisphere, consistent with the previously reported right-hemisphere bias for ventral parietal networks. We therefore support other evidence that the ventral parietal cortex plays an important role in feature binding, while the retinotopic dorsal areas of the parietal lobes show less involvement.

23.326 Motor effort predicts memory use in active visual search

Grayden Solman[1](grayden@psych.ubc.ca), Alan Kingstone[1]; [1]University of British Columbia

The role of memory for target locations in visual search has been the subject of considerable research, with important implications for naturalistic search – wherein target and distractor configurations are typically quite stable over time. In previous research, the authors have provided evidence that the use of memory during search is at least partly dependent on the difficulty of search (Solman & Smilek, 2012). In particular, it is proposed that as purely random (or 'brute force') search becomes more costly, searchers are more likely to use memory. This results in more robust effects of memory on search times and efficiencies when comparing search through repeated versus non-repeated displays. In the present work, we extend these findings to the embodied realm. Contrasting eye-driven and head-driven search, we examine search performance in repeated and non-repeated displays, evaluating RTs, slopes, and early orienting performance. In the eye-driven condition, participants searched via a gaze-contingent window with head position fixed. In the head-driven condition, we used motion-tracking equipment to produce a head-contingent window. By using a large screen and holding position constant, all stimulus dimensions including window size were matched across conditions with respect to visual angle. Comparing these conditions tests the hypothesis that there will be enhanced memory effects in head-driven search, extending the difficulty-dependent memory use hypothesis to the realm of physical / energetic cost. The results are particularly important in light of the necessary recruitment of multiple motor systems during naturalistic search, and suggest that caution is warranted when interpreting higher-order cognitive influences on search using only eye-movements.

Acknowledgement: NSERC, Killam Trust

23.327 Pupil Size as a Measure of Working Memory Load During a Complex Visual Search Task

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An observer's pupil dilates and constricts in response to changes in variables such as ambient luminance, emotional stimulus content, and working memory load. Although it is difficult to measure working memory load during an ongoing task, it is still possible to use pupil size as an indicator for this purpose to benefit many fields of research. One of the important domains in which pupillometry has been used to study cognitive processing is visual search. Porter, Troscianko, and Gilchrist (QJEP 2007) found that pupil size statistically increased over the course of the search, and they attributed this finding to accumulating working memory load. However, other factors, e.g., arousal and effort, likely affected pupil size as well and added noise to the data and some uncertainty to the conclusions. In the present study, we used a search task designed to increase working memory load by observers loading their memory with a number of targets and their different locations in the stimuli. We then analyzed their eye movements to examine their strategy in searching and investigated the interaction between eye movements and pupil size. The experiment interspersed Gabor patch search displays with intermittent blank screens showing only a central fixation marker, thought to induce a low, stable level of arousal and cognitive effort. Observers were to report the number of targets in each of four circles of search items in the stimuli. Consequently, differences in mean pupil size between successive fixation screens should mainly reflect changes in working memory load that occurred during the search interval between the fixation screens. The results show that (1) intermittent fixation screens greatly enhance pupil-based memory load estimation in complex search tasks; (2) eye-movements and strategy during search tasks can be valuable for enhancing pupil-based memory load estimation.

23.328 Cholinergic enhancement improves visual short-term memory performance

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Visual short-term memory (VSTM) refers to the retention of visual information from the immediate environment over brief intervals. In patients with mild cognitive impairment, pharmacologically increasing synaptic levels of acetylcholine (ACh) facilitates VSTM by boosting the rate of information processing (Bublak et al., 2011). We therefore hypothesized that cholinergic enhancement would improve VSTM performance in healthy subjects. Synaptic ACh levels were elevated by administration of the cholinesterase inhibitor donepezil in a placebo-controlled, double blind crossover design. Subjects were presented with a set of colored squares for either 100 or 200 ms. Consolidation of the set was disrupted by subsequent presentation of a visual mask. A second set of colored squares was then presented, and subjects were asked to report whether the second set was identical to the first or whether one of the squares changed color. In order to control task difficulty across subjects, we assessed the effects of donepezil for set sizes that were based on each subject's VSTM capacity (k), measured prior to the pharmacological manipulation. We found that for 100 ms stimulus presentation, cholinergic enhancement improved VSTM performance, consistent with the hypothesized role of ACh on information processing in VSTM. However, no effect of donepezil on VSTM performance was observed for longer stimulus durations (200 ms). Our results suggest that cholinergic enhancement improves VSTM only when performance is limited by the amount of time subjects view the material to be remembered.

23.329 Attentional Guidance in Visual Search: Examining the Interaction Between Goal Driven and Stimulus Driven Information in Natural Images

Natalie Paquette[1](paquette.n@gmail.com), Mark Neider[1]; [1]Department of Psychology, University of Central Florida

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In the real world, environmental cues help guide attention toward target-consistent regions. For example, Neider and Zelinsky (2006) found that observers restrict their gaze to ground areas when looking for a car in computer generated scenes. We continued exploring the role of semantic guidance, and how such top-down information interacts with bottom-up stimulus information, by examining search for spatially constrained targets in cluttered natural images. Specifically, we recorded eye movements while participants searched images of kitchens for a low-contrast target 'T' amongst similar 'L' distractors. Importantly, the target was always located in a region of the scene where a coffee cup would likely be found, with half of the participants given this information prior to beginning the experiment (context/no context groups). Target presence was also manipulated. In Experiment 1, the context group located the target more quickly (~547ms benefit of contextual information) than the no context group in target present trials, despite similar success rates (77% and 79% in the context and no context conditions, respectively). In Experiment 2, we evaluated whether the contextual guidance effect observed in Experiment 1 could be disrupted by making a single distractor 'L' more salient (a color singleton). The data were similar to Experiment 1. When there was no salient distractor, participants located the target faster (~741ms) when given contextual information. Furthermore, the contextual benefit persisted (~470ms) even in the presence of the salient distractor item. Taken together, our findings support the assertion that contextual information relating objects to likely spatial locations is not only important in visual search through real world scenes, but also provides a measure of insulation against distraction arising from task irrelevant differences in low-level stimulus properties.

23.330 **Action video game players can perform visual search faster, but show the same attentional capture** Jonathan Orozco[1](jlorozco23@gmail.com), Eriko Self[1]; [1]Department of Psychology, California State University, Fullerton

A visual search task was employed to investigate whether and how action video game players (AVGPs) surpass non-video game players (NVGPs). The methods were similar to Chisholm et al. (2010) with additional factors. In each trial, several green or red shapes were presented on the computer screen. Shapes were either circle (3.5° in diameter) or square (3.2° per side). Each shape contained a white line segment (1.5° x 0.2°). Three factors were manipulated to investigate the nature of difference between AVGPs and NVGPs: 1) the presence of distracter; all the shapes were the same color (distracter absent) or one shape was a different color than all the other shapes (distracter present), 2) spatial configuration; shapes were aligned on an imaginary circle of 14° radius or randomly located, 3) 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. Each of 34 AVGPs and 34 NVGPs ran 960 trials. The results of a 2 (AVGPs vs. NVGPs) x 2 (distracter presence) x 2 (spatial configuration) x 3 (number of shapes) mixed ANOVA indicated that AVGPs responded significantly faster than NVGPs [$F(1,66) = 2988.42$, $p=.014$]. All the three within-subject factors were also significant. However, we did not find any interaction between video game experience and the distracter presence as Chisholm et al. (2010) did. Video game experience did not show an interaction with the spatial configuration or the number of shapes, either. Accuracy percentage was not different between AVGPs and NVGPs [$F(1,66) <1$]. These results suggest that AVGPs can perform visual task faster than NVGPs overall, but do not show any less attentional capture.

Acknowledgement: State of California Mini-Grant to E Self

23.331 **Can blinking items ever capture attention in MAD search?** Melina Kunar[1](m.a.kunar@warwick.ac.uk), Derrick Watson[1]; [1]Department of Psychology, The University of Warwick

Previous work has found that search principles derived from simple visual search tasks do not necessarily apply to more complex search tasks. Using a Multi-element Asynchronous Dynamic (MAD) visual search task, where high numbers of stimuli could either be moving, stationary and/or changing in luminance, Kunar and Watson (2011) found that, unlike previous work, participants missed a high number of targets, search for moving items was worse than for static, and there was no benefit to finding targets that showed a luminance onset. Here we investigate why luminance onsets did not capture attention and whether luminance onsets can ever capture attention in MAD search. In the current series of experiments, we found that there was still no search benefit for blinking targets even when stimuli showed abrupt rather than gradual luminance onsets – conditions known to produce attentional capture in simpler visual search tasks. Subsequent experiments showed that giving participants pre-exposure to the blinking cues and advance knowledge of what the target would look like did not produce efficient search for blinking targets. However, a single blinking target did capture attention in MAD search conditions. Further studies found that unique motion also captured attention but, in contrast to other work, unique static targets were not found efficiently. The results rule out a no capture hypothesis, a unique magnocellular hypothesis, and a unique item hypothesis and instead favour a unique feature hypothesis of attentional capture in complex search.

23.332 **The contributions of expectancy and prior exposure to the surprise response in visual search.** James Retell[1](j.retell@uq.edu.au), Stefanie Becker[1], Roger Remington[1]; [1]School of Psychology, The University of Queensland

In the context of visual search, surprise is the phenomenon by which a previously unseen and unexpected stimulus exogenously attracts spatial attention. Capture by such a stimulus occurs, by definition, independent of tasks goals and is thought to be dependent on the extent to which the stimulus deviates from expectations (Horstmann, 2005, JEP:HPP). However, the relative contributions of prior exposure and expectation to the surprise response have not yet been systematically investigated. Here we investigated the extent to which surprise is related to never having seen a given stimulus before (exposure hypothesis) versus the extent to which a given stimulus violates task expectancies (expectation hypothesis). In a spatial cueing paradigm, observers had to search for a specific colour while ignoring irrelevant distractors of different colours presented prior to the target display (pre-cues). After a brief familiarization period, we presented an irrelevant motion cue to elicit surprise. Across conditions we varied prior exposure to the motion stimulus – seen versus unseen - and top-down expectations of occurrence – expected versus unexpected - to assess the extent to which each of these factors contributes to surprise. We found no difference in the magnitude of the surprise response associated with a previously seen but unexpected motion cue and a previously unseen but expected motion cue. These results suggest that the expectancies driving surprise may have different characteristics than previously thought and that surprise may be immune to cognitive strategies to attenuate it.

Face perception: Mechanisms and models

Saturday, May 11, 8:30 am - 12:30 pm

Poster Session, Orchid Ballroom

23.401 **Human and computer face detection under occlusion** Sam Anthony[1](santhony@wjh.harvard.edu), Ken Nakayama[1]; [1]Department of Psychology, Harvard University

The performance of computer algorithms that detect frontal face images has increased dramatically. However, numerous edge cases still exist where computer performance suffers compared to human ability; humans, able to detect faces from birth, perform at what can be considered an asymptotic level. We previously investigated the divergence between human and computer performance on a task that required detecting faces blended with phase-scrambled noise. Human performance greatly exceeded algorithmic performance on this task, but the stimuli were somewhat unrealistic, and thus a suboptimal benchmark for computer algorithms. Unlike phase-scrambled noise, occlusion is a common feature of natural scenes. Thus, in the present work we investigated the ability of humans and computers to detect heavily occluded faces. In the condition that produced the lowest human accuracy (faces composited over generated Portilla-Simoncelli textures with large, black occluding bars) subjects were able to achieve accuracies well above chance (57.6% mean accuracy on a 3-AFC task, N=409), and greatly exceeded the performance of the algorithms tested; successful detections by algorithms were near zero at levels of visibility where human performance approached ceiling. We investigated the nature of the difference between a range of computer algorithms and humans by using human performance information to gauge and scaffold both algorithm performance and the generalizability of trained classifiers. In typical machine learning training paradigms the training set is labeled only with a binary class identifier, but in our approach we integrate item-level accuracy, response time, and computed difficulty. This strategy of applying rich human performance data to the training and evaluation of algorithms points to promising techniques for increasing the performance and biological plausibility of face detection, face processing and other computer vision algorithms.

23.402 **The Neural Correlates of Recognizing Facial Slivers** Sharon Gilad-Gutnick[1,2](sharongu@mit.edu), Elia Samuel Harmatz[1], Kleovoulos Tsourides[1], Pawan Sinha[1]; [1]Brain and Cognitive Sciences, Massachusetts Institute of Technology, [2]The School of Psychological Sciences, Tel-Aviv University

Imagine vertically compressing a facial image to a quarter of its original width. Given the marked changes in facial configuration, one might expect that this grotesquely distorted face would be much less recognizable relative to the original. However, our current study demonstrates that identification performance remains almost entirely unaffected even at extreme compressions that result in sliver-like faces, no more than 1/6 the original width or height. Complementing this behavioral finding, we have recorded subjects' neural activity using Magnetoencephalography (MEG) as they viewed faces and objects that were subjected to a range of compressions. Our data reveal a striking correlation between behaviorally observed psychometric curve on the one hand and neural activity when viewing faces, on the other. Specifically, we found a significant change in amplitude and latency of the M170 and M250 components (implicated in face perception) at the same compression threshold at which behavioral recognition occurs. This result has important implications for linking neural activity and perception, as well as for understanding the nature of configural information that subserves face recognition. The tight coupling we observe between the M170 and behavioral performance is puzzling since past electrophysiological evidence linking this component to identity judgments is weak, at best. We propose an alternative explanation and also describe how our results help constrain the vague notion of 'facial configuration'.

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23.403 **Invariance to Linear But Not Non-Linear Changes in the Spatial Configuration of Faces in Human Visual Cortex** Timothy J Andrews[1](t.andrews@psych.york.ac.uk), Heidi A Baseler[1], Richard J Harris[1], Rob Jenkins[2], A. Mike Burton[3], Andrew W Young[1]; [1]Department of Psychology, University of York, York UK, [2]School of Psychology, University of Glasgow, Glasgow UK, [3]School of Psychology, University of Aberdeen, Aberdeen UK

The spatial relationships between the features of a face (known as second-order configuration) have been thought to play an important role in the recognition of identity. Despite such claims, however, behavioural studies have shown that geometric distortions that markedly affect this spatial configuration of a face image often have only a limited impact on judgements of identity. The aim of this study was to use fMRI to probe the sensitivity of face selective regions to geometric distortions that affect the spatial configuration of faces. In Experiment 1, participants viewed blocks of face images with same or different identity. There were 4 image manipulations: (1) unchanged, (2) linearly scaled, (3) linearly distorted (vertical stretch) or (4) non-linearly distorted (top half - unchanged, bottom half - vertical stretch). In the FFA, significant adaptation (different > same) was evident to unchanged, linearly scaled and linearly distorted faces. However, there was no adaptation to faces that were non-linearly distorted. These results suggest that linear distortions, which significantly affect the configuration of the face, continue to activate overlapping populations of neurons within face-selective regions. In Experiment 2, we explored sensitivity of face-selective regions to the more subtle types of non-linear change in the spatial configuration of faces that occur naturally across different individuals. We measured the response to blocks of composite images with the surface texture of one face, combined with the spatial configurations of different faces. Despite the smaller magnitude of these non-linear changes to the spatial configuration, no significant adaptation was evident in the FFA. This suggests that faces that have small non-linear differences in their spatial configuration activate non-overlapping populations of neurons in the face processing network. This differential sensitivity of face-selective regions to linear and non-linear changes in the spatial configuration of faces provides an important insight into the neural mechanisms underlying recognition.

Acknowledgement: Wellcome Trust

23.404 **Which feature is fixated modulates the N170 regardless of facial expression** Karly Neath[1](kneath@uwaterloo.ca), Roxane Itier[1]; [1]University of Waterloo

Facial expressions represent an important part of non-verbal communication used in everyday life. The N170 is widely regarded as a face-sensitive potential and has been linked to facial structural encoding, however it remains debated whether the N170 is modulated by facial expressions of emotion. We investigated how attention to facial features affects the early stages of emotion perception during an implicit emotion processing task. ERPs were recorded in response to presentations of fearful, joyful, or neutral facial expressions while fixation was restricted to the left eye, right eye, nose, or mouth using an eye tracker. Participants' task was to discriminate the face gender. Enhanced N170 amplitudes and longer latencies were found when participants were fixated on the left and right eyes compared to the mouth and nose irrespective of emotion. Importantly, the N170 was not modulated by emotion. The results support the view that the N170 component is not sensitive to the facial expression in an implicit emotional task. In contrast, which feature is fixated modulates this component. As the eyes have been shown to be the diagnostic feature used to correctly categorize face gender, it could be that attention to the diagnostic feature is what drives N170 modulation with emotion in previous studies not controlling for fixation. This idea is currently being tested using an explicit emotional task with the same stimuli.

23.405 **The N250r component indexes holistic perception of individual facial identity** John Towler[1](johntowler@hotmail.com), Martin Eimer[1]; [1]Department of Psychological Sciences, Birkbeck, University of London, UK

The composite face illusion is a well-known demonstration of holistic processing in face perception. However, little is known about the time course of neural processes that produce this effect. A repetition paradigm was employed where trials could contain repetitions of the same face, of two different faces, or of faces with the same top half but a different bottom half. The face halves were either aligned or misaligned. Participants had to judge whether the top halves of each face pair were identical or different, and to ignore the bottom halves. They were slower and less accurate in judging the top halves of a face pair as identical when the bottom halves were different, but only for aligned faces. Event-related brain potentials (ERPs) were measured during task performance to obtain N170 and N250r components as ERP markers of face perception and identity-sensitive face processing, respectively. The N170 component was larger in response to misaligned faces, reflecting a disruption of the canonical facial configuration. The N250r component was present for repetitions of identical aligned faces, but was eliminated when two identical top face halves were aligned with different bottom halves. This result shows that holistic representations of individual faces are available to be matched in visual working memory within 220ms after stimulus onset.

Acknowledgement: Economic and Social Sciences Research Council (ESRC)

23.406 **The Steady-State Visual Evoked Potential (SSVEP) response is more sensitive to face identity changes than bird identity changes** Buyun Xu[1](xubuyun@uvic.ca), James Tanaka[1], Bruno Rossion[2]; [1]Department of Psychology, University of Victoria, Canada, [2]Face Categorization Lab, University of Louvain, Belgium

The steady-state visual evoked potential (SSVEP) is a periodic EEG response elicited by periodic visual stimulation (Regan, 1966). The amplitude of SSVEP is reduced in response to repetitions of the same face compared to presentations of different faces (e.g., Rossion et al., 2012). Although the SSVEP technique is an ideal tool to study the sensitivity to face discrimination, it is unknown whether this effect is specific to faces or can be generalized to non-face objects. Here we tested the SSVEP response to face and bird stimuli at 4 Hz of stimulation frequency in 11 bird novices. Face and bird stimuli were gray-scaled and equated for luminance. Bird stimuli were selected from exemplars from different species. All trials started with the presentation of an identical stimulus for 15 seconds followed by 75 seconds of presentation in which the identity of the stimuli either remained the same or changed at every cycle. The stimuli were presented in varying sizes to control for adaptation to low-level properties. Fourier Transform was applied to EEG recordings (32 channels) from the 18th to 67th second of presentation (frequency resolution: 0.02 Hz). Replicating previous observations, responses at both the fundamental frequency (4 Hz) and the second harmonics (8 Hz) were larger for different faces than the same face condition at occipito-temporal electrode sites. However, there was no difference at 4 Hz for bird stimuli, and only a weak effect at the second harmonics (8 Hz). This effect is not attributable to image similarity because physical differences between bird stimuli were larger than face stimuli. These results indicate that the SSVEP is sensitive to the identity differences in faces, but not to identity differences in non-face objects, such as birds.

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23.407 **Objective measurement of face discrimination with a fast periodic oddball paradigm** Joan Liu-Shuang[1](joan.liu@uclouvain.be), Anthony M. Norcia[2], Bruno Rossion[1]; [1]Face Categorisation Lab, University of Louvain, [2]Department of Psychology, Stanford University

The mechanisms underlying visual objects perception remain poorly understood, especially for visually homogenous categories such as human faces. We propose a novel paradigm using fast periodic oddball stimulation to objectively and rapidly quantify individual face discrimination, separately from a general response to faces. We recorded 128-channel EEG in 20 observers presented with 60-second sequences of face stimuli shown at a constant

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frequency of 5.88 Hz. One face (A) was repeated throughout each sequence. Different "oddball" faces (B, C…) were introduced at fixed intervals (every 5 faces: 5.88 Hz/5 = 1.18 Hz), resulting in the following sequence structure: AAAABAAAAC... The responses at 1.18Hz and its harmonics (2F = 2.35 Hz, 3F = 3.53 Hz…) were taken as an index of face discrimination. To isolate high-level face perception, we manipulated size (face size randomly varied every cycle), orientation (upright vs. inverted, Experiment 1) and contrast (normal contrast vs. contrast-reversed, Experiment 2). In both experiments, normal faces evoked highly significant responses at 1.18 Hz and its harmonics, particularly on right occipito-temporal channels. Inversion and contrast reversal significantly reduced the oddball responses, while the basic 5.88 Hz response did not differ between conditions. In Experiment 3, we tested the fast oddball paradigm with upright faces in a well-known case of acquired prosopagnosia, PS (Rossion et al., 2003, Brain), who is specifically impaired at individual face perception (e.g., Busigny et al., 2010, Neuropsychologia). Although PS' general periodic response to faces (5.88 Hz) did not differ from young controls (N=11), her right occipito-temporal oddball response (1.18 Hz and its harmonics) was significantly reduced compared to controls. These observations underline the interest and high diagnosticity of the fast oddball paradigm to assess face discrimination on a neural level.

Acknowledgement: Fonds National de Recherche Scientifique

23.408 **Differential Selectivity and Representational Content of the Fine Scale Face-Responsive Regions**

Hanyu Shao[1](shaohanyu@hotmail.com), Qiuping Cheng[1], Sheng He[2], Xuchu Weng[1]; [1]Center for Cognition and Brain Disorders,Hangzhou Normal University, [2]Department of Psychology, University of Minnesota

High-resolution fMRI have identified six face-responsive regions in the left and right ventral occipital-temporal cortex (mFus-medium fusiform; pFus-posterior fusiform; and IOG-Inferior Occipital Gyrus), but the degree and nature of these regions' face selectivity and their information representation are not yet clear. Here, we use single-image approach combined with regional-average activation and representational connectivity analysis (RCA) to investigate their selectivity and representational properties. The mean response level and the representational dissimilarity matrix associated with 96 object images from 16 categories were computed for each ROI to characterize their selectivity and representational content. In terms of the mean responses, R-mFus showed the highest degree of response specificity to faces, whereas the other five regions showed much weaker face preference. In terms of the spatial patterns of the responses, all ROIs had small dissimilarities between individual faces compared to other image categories, indicating a more consistent spatial response to faces. In the MDS plot reflecting relationships between different ROI's representational properties, R-IOG, L-IOG , L-mFus, L-pFus typically formed a tight cluster whereas R-pFus and R-mFus were loosely related, with R-mFus most distinguished from the other ROIs. Further RCA confirmed this relationship and showed that certain pairs of objects eliciting more dissimilar response patterns in R-mFus tended to elicit more dissimilar responses patterns in R-pFus, and for the majority pairs of objects the same held for pairwise correlations of L-mFus, L-pFus, L-IOG and R-IOG. Our findings show that R-mFus had the highest face selectivity among all regions and the most distinct spatial representation of the 96 images, followed by R-pFus; while the representations of L-mFus, L-pFus, L-IOG and R-IOG were similar to each other and generally less face-selective.

23.409 **Development Model of Face and Object Recognition Using Modular Neural Network**

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Extensive research effort has been put onto building computational models for face and object recognition. However, how to best combine a recognition model with the development of the human visual system remains an open question. Research in contrast sensitivity shows the infants can only receive low spatial frequency information from visual stimuli, and their ability to receive full frequency information cannot achieve adult levels until 10 years old. Also, the right hemisphere (RH) learns earlier and faster than the left hemisphere (LH), and the RH is dominant in infants. It is also known that face recognition is low-frequency biased and RH lateralized. Combining these observations, we propose a developmental model of object recognition using a modular neural network based on (Dailey and Cottrell, 1999). In this model, each visual stimuli is preprocessed through Gabor filter banks followed by PCA at each spatial frequency. The neural network has two modules to represent the two hemispheres and one hidden layer for each module. The output of the neural network is modulated by a gating network, which learns to gate the contribution of each module to the output, based on their contribution to performance. To model changes in infant acuity, we low-pass filter the data set, and gradually increase fidelity over training. To model the asymmetric developmental pattern, we give the two modules different learning rate over time. The right hemisphere bias for face processing emerges naturally from this process as the gating node value of the right hemisphere always prevails over the left hemisphere for face images. Hence we propose that the RH bias for faces arises from the interaction of these two developmental trends.

23.410 **Effects of grouping on neural competition in object category selective cortex**

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Single-cell electrophysiological studies have shown that multiple stimuli presented simultaneously in the cell's receptive field compete for representation by mutually suppressing neural responses. Suppressive interactions among multiple stimuli have been also reported in fMRI studies that showed lower fMRI signal to simultaneously presented stimuli than to the same stimuli presented sequentially. These fMRI studies have so far examined such competition effect only for low-level stimuli (e.g. gabor patches). In the present study we examined neural competition among high-level visual stimuli (i.e., faces and bodies) in object category selective cortex to answer the following questions: Does neural competition in object category selective cortex exist? Is competition reduced for two objects that can be grouped to a single object (i.e. a face above a body)? To that end, we presented pairs of faces and headless bodies above and below fixation simultaneously or sequentially. Subjects performed a fixation task so the two stimuli were unattended. Our results show significant competition effect between two faces presented simultaneously in the face-selective areas, and between two bodies presented simultaneously in the body-selective areas. Interestingly, neural competition was markedly reduced when a face was presented above a body, generating the perception of a person, but not when a body was presented above a face. This effect was larger in ventral temporal than in lateral occipital face and body areas. Our findings show that neural competition between multiple object stimuli in object category selective cortex exists. They also show that competition in object-selective areas occurs between objects, and not between features within an object, therefore, once stimuli are grouped together, they are perceived as a unit rather than two competing stimuli, and neural competition is reduced.

Acknowledgement: Israel Science Foundation grant 446/12 to GY

23.411 **Functional relationship between the left and right fusiform face areas**

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The hierarchical relationship in the ventral visual pathway, e.g., from occipital face area (OFA) to fusiform face area (FFA) has been studied to analyze neural stages of face processing. Interestingly, studies have also shown the hemispherical asymmetry of face processing. The left FFA appears to be most heavily involved in analyzing image-level face-semblance, while activity in the right FFA correlates with categorical perceptual decision of whether a visual input is a face (Meng, Cherian, Singal, & Sinha, 2012). However, it remains unknown whether the processes of the left FFA and those of the right FFA occur in parallel or whether the two are serially dependent. Using a collection of 300 stimulus images (including 60 random nonface images, 180 false alarms from a computer face detection system, and 60 genuine face images), we evaluated the strengths of relationships between a feature-based measurement of face-semblance and the multivariate activation pattern correlations measured by fMRI of the left and right FFAs. The feature-based face-semblance metric was computed for each image by detecting the presence of 12 contrast polarity relationships between face areas specified by the Sinha model (Sinha, 2002), e.g. forehead is brighter than left eye and summing the number of relationships (face features) fulfilled by that image (Ohayon, Freiwald, & Tsao, 2012). Partial correlation analyses reveal that, removing the influence of right FFA, left FFA activity significantly correlates with the face feature measure for both nonfaces and the whole stimulus set. By contrast, when the influence of left FFA is removed, right FFA activity does not correlate with the face feature measure. These results suggest that left FFA activation may precede and influence right FFA activation. Unlike the right FFA that appears to only deal with faces, the left FFA may process image-level semblance in nonfaces in addition to faces.

Acknowledgement: National Science Foundation

23.412 Neural representations in face-selective regions are affected by task, stimulus and information content

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Establishing the functional role of brain regions will require a better understanding of the interactions between stimulus information in the input and the subset of this information the brain requires to categorize the stimulus as one thing or another (Schyns, 1998; Pernet et al., 2007). Of the distributed face-preferential regions there are inconsistencies regarding their functional roles. To illustrate, while some studies indicate that the OFA is crucial for processing of identity (Dricot et al., 2008; Kadosh et al., 2011), whereas others suggests that it is involved in processing of generic facial features (Gilaie-Dotan et al., 2010). We addressed the functionality of face-preferential regions in a fast event-related fMRI experiment using different categorizations of faces and objects (male vs. female, or fruit/vegetable decisions on the one hand, identification of exemplars on the other) and parametrically varied the stimuli in terms of their Spatial Frequency (SF) content. We first measured observers' behavioral performance with each combination of categorization and stimulus, across the different levels of SF content. To ascertain which brain regions code the categorical information, we sampled voxels from the bilateral OFAs and FFAs, built similarity matrices for each conjunction of categorization task and stimulus set (e.g. gender/faces vs. identity/faces) and tracked the regions whose categorical discrimination matched the observers' behavioral performance. Neural representations generally differentiated with increasing stimulus resolution, but this differentiation followed the specific categorization considered (e.g. gender coding in gender and identity coding in identity task). These findings are in agreement with studies showing stimulus- and/or task-dependent modulation of activation within category-specific regions (e.g. Joseph et al., 2006; Cohen Kadosh et al., 2010) and task-context dependent responses in sub-populations of IT neurons (Pauls & Logothetis, 2002).

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23.414 Development of Right Inferior Longitudinal Fasciculus Correlates Specifically with Face Perception

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Human high-level visual cortex contains a constellation of functionally defined regions showing preferential neural responses to specific categories of visual stimuli, such as face-selective regions in the fusiform gyrus (FFA). While our lab has demonstrated that the development of the FFA correlates with face recognition memory from childhood to adulthood, how the concurrent development of neighboring white matter relates is still unclear. We used diffusion tensor imaging (DTI) in 13 children (aged 7-11), 11 adolescents (aged 12-16), and 9 adults (aged 18-40) to deterministically track visual association fibers connecting the occipital lobe to the anterior temporal lobe (inferior longitudinal fasciculus, ILF) and to the frontal lobe (inferior fronto-occipital fasciculus, IFOF). We then correlated resultant fiber properties (fractional anisotropy (FA), radial (RD) and mean diffusivity (MD)) with several behavioral measures, including the Benton face perception task, recognition memory tasks for faces, places, objects, and cars, and the abbreviated scale of intelligence (WASI). Anatomically, we observed prolonged development of both the ILF and IFOF in both hemispheres, with FA significantly lower in children than adults (Fs > 5.1 , ps < .01). Behaviorally, performance on the Benton face perception task was the only measure that showed a significant correlation with white matter properties across subjects. Specifically, there was a significant correlation between Benton performance and FA values of the right ILF, even after controlling for the effect of age ($r = .58$, $p = .01$). This correlation was highest in posterior portions of the ILF and decreased anteriorly. These results demonstrate that large fiber tracts connecting the ventral stream to the anterior temporal and prefrontal lobes undergo prolonged development into adulthood. Moreover, our data suggest that the structural integrity of the right ILF is important for face perception proficiency and that lesions to this tract may impair such perception.

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23.415 Robust Selectivity for Faces in the Human Amygdala

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There is a well-established posterior network of cortical regions that plays a central role in face processing and has been investigated extensively. In contrast, while responsive to faces, the amygdala is not considered a core face-selective region and its face selectivity has never been a topic of systematic research in human neuroimaging studies. Prior fMRI studies relied on localizer tasks in which participants are presented with photographs of faces and objects from other visual categories (e.g., houses) to identify face-selective BOLD responses. We show that the lack of focus on the face selectivity of the amygdala results from limited statistical power in the standard localizer approach. First, the amygdala's small size and location make it difficult to image because of a reduced signal-to-noise ratio relative to cortical regions. Second, group analyses of localizer data are not typically reported to avoid cortical misalignment, which compounds the problem because of increased measurement error. To overcome these challenges, we performed group analyses of functional localizer data from over 200 human participants across 10 studies, using emotionally neutral faces and various visual control categories. Beyond the posterior network of cortical regions observed in prior studies, we found robust face-selective responses in the amygdala, which displayed high reliability over time. Furthermore, examining the covariance of reliability scores across face-selective regions revealed separable cortical and subcortical face-processing networks. Finally, connectivity analyses confirmed a context-dependent relationship between the amygdala and fusiform, whereby functional connectivity between these regions increased during face presentations, compared to control stimuli. These results bridge a gap between single-unit recording studies — where face selectivity has been better characterized — and neuroimaging studies, suggesting that the amygdala has comparable face selectivity to putative "face" areas in posterior visual cortex, and providing some of the first evidence that subcortical regions can be specialized for high-level cognitive processes.

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23.416 Mostly Categorical but also Continuous Representation of Emotions in the Brain: An fMRI study

Shichuan Du[1](du.64@osu.edu), Dirk Walther[2], Aleix Martinez[1]; [1]Department of Electrical and Computer Engineering, The Ohio State University, [2]Department of Psychology , The Ohio State University

The old question of how emotions are represented in the brain has resulted in a fierce debate between the proponents of the continuous versus categorical models. The continuous model argues for the same set of brain regions to differentially respond to all emotion categories. In contrast, the categorical model argues for a distinct set of areas consistently and specifically active for distinct basic categories of emotion. To test these two models, we use fMRI to determine whether the brain regions associated with the perception of six basic facial expressions of emotion (happiness, surprise, sadness, anger, disgust and fear) plus neutral best fit the continuous or the categorical model. We used a block design with eight runs of fourteen blocks each. Each block includes six sample images of the same emotion category. Each face is shown for 1.5 seconds followed by a blank screen for .5 seconds. Blocks are separated by 13 seconds with blank screen. Category order in each run is randomized. After each run, subjects are shown two images and asked to indicate which of the two images had been previously shown by button press. Five subjects successfully completed the task. We used searchlight with linear discriminant analysis to classify each pair of categories in a leave-one-block-out test, yielding 70% to 90% classification accuracy (chance 50%) in each subject with $p<.05$. The most discriminant areas were then mapped into a standard brain to identity common areas. Only regions consistently active in at least four subjects were kept. Most identified brain regions are consistently and specifically active for one category only (e.g., left SFG for happiness), but a few are common over several categories (e.g., left STS in sadness, anger, fear and surprise). These results suggest the brain includes a categorical and a continuous representation of facial expressions of emotion.

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23.417 Neural model for the encoding of dynamic faces in primate cortex

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Natural facial expressions are essentially dynamic. However, only few research has investigated the neural mechanisms of the processing of dynamic faces. Exploiting well-established as well as novel physiologically plausible neural mechanisms, we try to reproduce data on the neural processing of dynamic faces, exploring different neural encoding principles that have been shown to relevant for the neural encoding of shapes and faces.

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Methods: We devised alternative, physiologically plausible hierarchical neural models for the recognition of dynamic faces that simulate the properties of neurons in face-selective regions, such as the STS or area IT. The model is based on a previous physiologically-inspired models of the processing of static faces [Giese & Leopold, 2005,Neurocomputing 65-66, 93-101]. These models exploit learned hierarchies of feature detectors, where mid-level features are optimized by unsupervised learning. On the highest hierarchy level we implemented different possibilities for the encoding of dynamic faces, exploiting norm-referenced, as well as example-based encoding, together with dynamic neural mechanisms to integrate information over time. The model was tested on video data bases with monkey as well as with human facial expressions. Results: Models based on both coding principles, example- as well as norm-referenced encoding, work successfully and permit to classify monkey and human expressions from real videos correctly. They make specific unique predictions at the level of single cell activity in dynamic face-selective regions. The norm-referenced mechanism was more robust in some cases. Conclusions: Simple physiologically plausible neural circuits can account for the recognition of dynamic faces. Data from single-cell recordings will allow to decide between different models.

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Motion: Biological motion

Saturday, May 11, 8:30 am - 12:30 pm

Poster Session, Orchid Ballroom

23.418 Event-related alpha suppression in response to facial motion.

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Introduction: Research has associated reductions in the alpha power of occipital and parietal EEG (alpha suppression) with visual attentional processes and memory load performance. The purpose of the current EEG study was to determine the effect of facial (biological) motion on alpha suppression. Methods: Participants viewed a continuous stream of averaged facial motion captures. The animations exhibited natural motion, were realistic in appearance and only differed in the way they moved (Hill & Johnston, 2001). The task was to discriminate between successive motion animations by indicating whether they were the same or different. Upright, inverted and polarity-inverted facial stimuli were compared. The amplitudes and latencies of maxima and minima alpha power were analysed across occipital and parietal-occipital visual areas. Results: There was an overall effect of face type on alpha at parietal-occipital locations. Although each face type reduced alpha power, there are some considerable differences to note. Relative to baseline (-100 ms to 0 ms onset), upright facial motion evoked the highest alpha amplitudes at 400 – 500 ms post onset and the most subsequent suppression compared to other stimuli. Suppression in response to upright facial motion also occurred earlier than for other face types (upright 730 ms; polarity-inverted 733 ms; inverted 754 ms). Similar observations were made at occipital sites. Conclusion: Upright facial motion is processed earlier and more efficiently than other facial motions. This highlights its importance as a mediator of social cognition (e.g. identification, emotion recognition, inferring intentions). Differential suppression at occipital and parietal-occipital sites indicates that visual processing of facial motion is affected by experimental manipulations such as inversion and polarity reversal. However, each face type reduced alpha power to some extent, implying that the visual substrates are active and trying to make sense of the visual scene regardless of manipulation.

23.419 Retaining biological motions in working memory: an EEG study

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Biological motions transfer important social information, playing a critical role in our life. Previous studies suggested that human mirror neuron system (hMNS) gets involved in the understanding of biological motion. It has been demonstrated that the mu (8–12 Hz) range, which is suggested to have a direct link with hMNS, is significantly suppressed when perceiving biological motions relative to non-biological motions. However, all previous studies addressing biological motions investigated their mechanisms at a perceptual stage (e.g., extracting social information from a displayed biological motion). In many situations we need to keep the biological motion information in working memory to fulfill tasks, yet, to our knowledge, how the biological motions are retained in working memory remains unknown. Here we explored this issue in two experiments, by adopting point-light displays as the stimuli of interest in a change-detection task. The memory load of biological motions was manipulated. We found that the amplitude suppression of mu range was modulated by the memory load: the amplitude suppression increased as the memory load rose, but leveled off at 4 biological motions. Moreover, the number of biological motions retained in working memory is positively correlated with the amplitude suppression of mu range. These results suggest that hMNS plays a critical role in retaining biological motion in working memory, by rehearsing the biological motions via the mu range.

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23.420 A data-driven approach to functional selectivity on the STS

Emily Grossman[1](grossman@uci.edu), Sarah Tyler[1], Samhita Dasgupta[1], Elizabeth Hecker[1], Javier Garcia[2]; [1]Department of Cognitive Sciences, Center for Cognitive Neuroscience, University of California Irvine, [2]Department of Psychology, University of California San Diego

Attention to visual features increases the firing rate for neurons tuned to those features (e.g. Saenz, Buracas & Boynton, 2002). In this study, we measure the effects of attention to point-light biological motion on neural activity in human STS, a brain area believed to have neural populations tuned to distinct actions (e.g. Grossman, Jardine & Pyles, 2010). Methods. Observers viewed a 1 sec animation of a centrally positioned point-light walker. A 50ms square appeared 3deg in the periphery at 300ms or 600 ms after the onset of the walker. In different blocks subjects were instructed to report 1) the facing direction of the walker (attend to walker, ignore flanker), 2) the position of the flanker (ignore walker, attend to flanker), or 3) the facing direction of the walker, but hold the response until the flanker appeared (attend to both). Results. Principal component analysis on the STS BOLD response revealed three spatially distinct subdivisions within the independently localized STS. Neural activity in the fundus of the STS was strongest when subjects attended to the biological motion, while the most dorsal aspects of the STS were more activated when monitoring for the peripheral flanker. The most anterior regions of the STS deactivated during all three attention tasks. Functional connectivity analyses revealed these regions to be correlated with homologous regions in the opposite hemispheres, but not with each other (even within the same hemisphere). Conclusions. Our findings reveal a coarse cortical organization in the STS during action recognition. The increased neural activity in the STS fundus likely reflects a gain in action selective neurons as a result of attending to the biological motion. The other subdivisions of the STS likely reflect the domain-general attentive demands of perceptually organizing biological motion.

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23.421 Representations of action categories generalize across the phylum, genus, and species of the actor

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Neuroimaging studies of action representation frequently investigate activity associated with viewing human actions. However, many actions are general with respect to the kinds of animals that can perform them. It is just as easy to recognize “eating” whether done by beetle or bear. We investigate the generality of action representations and dissociate representational dimensions that reflect action category versus animal category. Undergoing fMRI, subjects viewed 24 video clips that depicted a range of animals---primates to ladybugs---performing different actions: eating, fighting, running, swimming. Using a voxel clustering procedure (Connolly et al. 2012) we produced “early” and “late” vision ROIs (“EV” and “LV”). SVM classification in EV and LV yielded mean accuracies of 0.75 and 0.60, chance = 0.04 (1/24). We analyzed the structure of representational spaces using multi-table MDS (Abdi et al. 2012). In LV, the first, third and fourth dimensions of the solution distinguished between different types of actions, with the 1st dimension distinguishing all action pairs except for fighting versus swimming. Dimension 3 distinguished fighting from eating and running, and 4 distinguished swimming from others. Dimension 2 separated mammals from non-mammals and contained no action information. EV carried information about action classes to a lesser degree: Dimension 1 distinguished between swimming versus eating and fighting, and dimension 3 between running and others. Again, dimension 2 separated the mammals from non-mammals. Next we used searchlight analysis to classify each clip into action categories. This analysis revealed maps of action representation networks including posterior middle temporal cortex---including pSTS

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and extending into LOC---and IPS. Searchlight analysis for mammal vs. non-mammals produced peaks in posterior lateral occipital cortex. In sum, these results provide evidence for abstract action representations that generalize across the species of the actors. Separate components of an overlapping distributed representational space reflected action and animal categories.

23.422 **Action classification through a new reverse correlation technique: the feet are important, as well as their correlated motions** Jeroen J.A. van Boxtel[1](j.j.a.vanboxtel@gmail.com), Hongjing Lu[1,2]; [1]Psychology Department, University of California - Los Angeles, [2]Statistics Department, University of California - Los Angeles

Humans frequently face situations that require the interpretation of actions of another person. It is still largely unknown what information is used by observers to perform action recognition tasks. We employed a new reverse correlation technique to uncover which information is used in the discrimination of point-light walkers and runners. The actor consisted 13 dots on the main joints, the actor rotated in depth (150deg/s), and presentation time was 1 cycle = ~1 sec. Walker and runner cycle lengths were identical. Each trial, observers viewed a point-light actor of which the joints were individually morphed between walker and runner actions, with randomly assigned weights taken from a normal distribution (mean (SD) = 0.5 (0.25)). Weights falling outside the 0-1 range were redrawn. Subjects classified each trial as a walker or runner. The data were submitted to a logistic regression, and we extracted the beta value (i.e., strength) of each joint in the discrimination process, as well as the correlation matrix (determining the interaction between joints). In independent experiments we found that the weight of the feet significantly influenced the discrimination process. The correlation matrix revealed that the feet are also positively correlated (i.e., observers paid attention to both feet concurrently). Additionally, several positive correlations existed between the upper and lower body, mainly between the wrists/elbows and the feet. Previous research had indicated that the feet are important in determining the facing and walking direction of an actor (Troje & Westhoff, 2006, Curr Biol). Our method confirms the importance of the feet in another task (walking versus running discrimination), and did so using a hypothesis-free reverse correlation technique. A further advantage of this technique is its generalizability to any type of action discrimination task (e.g., boxing vs. walking, or boxing vs. waving), and that it reveals inter-joint interactions.

Acknowledgement: This research was supported by NSF grant BCS-0843880

23.423 **Does a convexity prior explain the facing-the-viewer bias in the perception of biological motion?** Séamas Weech[1](seamas.weech@queensu.ca), Nikolaus F. Troje[1]; [1]Department of Psychology, Queen's University

Point-light walkers generally contain no information about their orientation in depth, yet observers consistently prefer the facing-the-viewer (FTV) interpretation (Vanrie et al., 2004). Some research (Schouten et al., 2011) suggests that local stimulus properties elicit the bias: Presentation of the lower half of point-light figures elicits a pronounced FTV bias, while presentation of the upper half does not. Other research suggests high level causes: Male walkers generate a stronger FTV bias than female walker (Brooks et al., 2004). Interestingly, no FTV biases are observed with human silhouettes (Troje & McAdam, 2010). We hypothesise that the FTV bias is due to a convexity prior (Mamassian & Landy, 1998). Accordingly, the knees afford a FTV interpretation while the elbows, specifically when pointing back (as typical for women) rather than sideways (as in males), afford a facing-away interpretation. This requires visual structures other than occluding contours which are neither concave nor convex with respect to the line of sight. Here we asked observers to indicate perceived rotation directions (clockwise/counter clockwise) of a silhouette of a crouching human figure with knees pointing forward and elbows pointing back. Four conditions were included: silhouettes presented with no markers, with markers at the centre of the knees, with markers at the centre of the elbows, and with markers on both knees and elbows. We measured facing bias as the proportion of depth reversals from the 'away' to the 'toward' interpretation. The silhouette alone elicited a weak facing bias, as did the silhouette with both elbow and knee markers present. As predicted, silhouettes with knee markers only elicited a FTV bias while elbow markers alone elicited a notable facing away bias. These results help to interpret and unify various findings regarding the FTV bias, and support the idea that an experientially-driven convexity prior guides interpretations of depth-ambiguous figures.

Acknowledgement: This research was funded by grants from NSERC and CIfAR to NFT.

23.424 **Can we perceive linear perspective in biological motion point-light displays?** Nikolaus Troje[1,2,3](troje@queensu.ca), Seamas Weech[1], Sophie Kenny[1]; [1]Psychology, Queen's University, [2]Computer Science, Queen's University, [3]Biology, Queen's University

Orthographically projected point-light walkers are ambiguous with respect to depth. For instance, fronto-parallel views from the front and from the back of a bilaterally symmetric walker result in identical projections. In a number of recent studies it was shown that the introduction of linear perspective can gradually disambiguate perceived facing direction. This observation seems to imply that observers are sensitive to linear perspective in point-light displays. We hypothesize that effects of using an approaching perspective camera have nothing to do with linear perspective per se, but with the fact that the camera looks down at the feet – at least when its vertical location is above ground level. The two hypotheses can be distinguished experimentally: If the effect is due to linear perspective, only distance between camera and walker matters. If it is a result of looking down at the feet, the camera elevation angle (height/distance) determines the effect. Using a staircase procedure, we measured PSE and slope of the psychometric function relating percentage of perceived facing direction to the amount of perspective (quantified in terms of field-of-view angle, i.e. the visual angle subtended by the walker) in 10 participants. Three vertical camera levels were used within-subjects: feet-level, half walker height, and head-level. As the camera is lowered from head- to mid-level, field-of-view angles at PSE increase from 3.8 deg to 6.7 deg, and the slope of the psychometric function decreases from 3.7 %/deg to 2.4 %/deg. If the camera is at floor level the field-of-view angle never converges to a stable value, reaching a nominal PSE of 43 deg and a slope of only 0.55 %/deg at the end of a 80-trial staircase. The data imply that it is not perspective, but the projection of the feet seen slightly from above that dis-ambiguates the perceived facing direction of the walker.

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23.425 **Discriminating implicit and explicit emotions from point-light walkers in persons with schizophrenia** Justine M. Y. Spencer[1](spencjmy@mcmaster.ca), Allison B. Sekuler[1], Patrick J. Bennett[1], Martin A. Giese[2], Bruce K. Christensen[3]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University, [2]Department of Cognitive Neurology and Centre for Integrated Neuroscience, University of Tübingen, [3]Department of Psychiatry & Behavioural Neurosciences, McMaster University

The visual system is well adapted to recognize human motion from point lights attached to the major joints of an actor. Moreover, individuals are able to recognize emotions based on the visual information in such dynamic point-light displays. This ability is important because humans utilize both biological motion and affect recognition for understanding the intentions of others. Previous studies have demonstrated that people with schizophrenia show impaired performance for explicit visual recognition of emotional point-light walkers, which may contribute more generally to social perception deficits seen in this population. However, our interactions with others are governed by both explicit and implicit visual processes, and it is not clear whether people with schizophrenia process explicit and implicit emotion derived from biological motion in the same way as healthy observers. In the current study, healthy community-based controls (N=33) and people with schizophrenia (N=33) were asked to discriminate the emotions of morphed point-light walkers along three dimensions: happy-angry, happy-sad, and sad-angry. Additionally, stimuli were morphed along a continuum, in which the emotional point-light walkers represented both explicit (i.e., 100% happy and 0% angry) and implicit (i.e., 60% happy and 40% angry) emotion presentation. Using a curve-fitting procedure, slopes of the resulting psychometric functions were used to evaluate implicit processing of emotion, while upper and lower asymptotes were utilized to characterize the explicit processing of emotion. Overall, healthy observers and people with schizophrenia were observed to have similar slopes. However, analysis of both lower and upper asymptotes revealed significant differences between the two groups, despite the fact that performance generally was higher for explicit than implicit stimuli. These results suggest that while people with schizophrenia show perceptual deficits in the recognition of explicit emotion classification from point-light walkers, the processing of implicit emotions seems to be preserved.

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23.426 Recognition of emotion through point-light locomotion: gender impact Marina A. Pavlova[1](marina.pavlova@uni-tuebingen.de), Samuel Krüger[1], Alexander N. Sokolov[2], Ingeborg Krägeloh-Mann[1]; [1]Children's Hospital, University of Tübingen Medical School, [2]Department of Psychosomatic Medicine and Psychotherapy, University of Tübingen Medical School

Veridical body language reading is important for daily-life social interaction and competence. Yet it is unclear whether the ability for veridical body language reading is impacted by gender. According to popular wisdom about female superiority in social cognition, females are reported to surpass in some aspects of body language reading. However, the existing data are sparse and controversial (Alaerts et al., 2011, PLoS One 6: e20989; Sokolov et al., 2011, Front Psychol. 2: 16). In the present work, female and male healthy young observers had to recognize emotions through point-light human locomotion performed by female and male actors with different emotional expressions (happy, angry, or neutral). For subtle emotional expressions, males surpass females in recognition of happy walking portrayed by female actors, whereas females tend to excel in recognition of hostile angry locomotion expressed by male actors. The lack of gender differences in error rate suggests that gender effects on recognition accuracy of emotions through locomotion are not caused by gender-related bias for misperceiving one emotion for another. In contrast to widespread beliefs about female superiority in body language reading, the findings suggest that gender effects in recognition of emotions from human locomotion are modulated by emotional content of actions and (opposite) actor gender. In a nutshell, the study makes a further step in understanding of gender impact on body language reading. Clarification of gender impact on body language reading and underlying brain networks would provide novel insights into understanding of gender vulnerability to neuropsychiatric and neurodevelopmental impairments in social cognition (Pavlova, 2012 Cerebral Cortex 22: 981-995).

23.427 Tactile inputs resolve the ambiguous perception of biological point light walkers Yiltiz Hormatzhan[1](clh20000@gmail.com), Lihan Chen[1,2]; [1]Center for Brain and Cognitive Sciences and Department of Psychology, Peking University, [2]Key Laboratory of Machine Perception (Ministry of Education), Peking University

Point light walker (PLW) has been widely applied to address the biological motion processing in the visual modality. Biological PLW has been recently employed in multisensory research, in which task-irrelevant auditory cues would bias the perception of walking direction of ambiguous PLWs (Brooks et al., 2007). In current study we asked whether the tactile inputs, which simulate the hitting grounds by foots, could affect the ambiguous directional perception of PLWs. We presented binocular rivalry PLWs with 13 red and 13 cyan dots, the two PLWs could be either upright or either inverted. One tap was always synchronized with the hitting of the visual foot of one PLW, and the other tap could lead (150 ms), synchronize or lag (150 ms) the other hitting foot of this PLW. Participants wore glasses with a red filter on the left eye and a cyan filter on the right eye during the course of the experiments and performed two tasks: (1) Motion Direction Determination ("Motion" task)-they were asked to press and hold the left or right foot switch which corresponds to the dominant perception of "left" or "right" direction of the PLWs ; (2) Visual Dots Number Comparison ("Number" task), in which the participants were required to discriminate whether red dots were more than cyan dots or vice versa. The results showed the synchronous inputs of tactile taps increased the delectability of motion directional discrimination in "upright" condition but it was not the case in the "invert" condition. Interestingly, for the "Number" task, the PLW synchronized with the tactile inputs were perceived to be more in dots. These findings suggest that tactile inputs, which consist of apparent motion, affect the visual apparent motion of PLW, this effect could not be reduced to a general shift in visuo-spatial attention, as reflected in the Number task.

23.428 Combining detection and discrimination of biological motion at low contrast Sarah Dziura[1](sdziura@masonlive.gmu.edu), Wendy Baccus[1], James Thompson[1]; [1]Psychology, College of Humanities and Social Sciences, George Mason University

Studying the way humans perceive body form and motion cues is important in understanding how we recognize and respond to human actions. Due to the nature of visual processing pathways, one way to independently manipulate these cues is to vary stimulus contrast. In this study we examined the effects of contrast on a task that combined detection and discrimination of human actions in intact biological motion, scrambled biological motion, and static form conditions. We used a two-stage forced choice paradigm so we could directly compare detection and discrimination performance on a trial by trial basis. Participants (N=15) first determined in which of two intervals a stimulus was presented, and then chose which of four actions (boxing, leaping, running, or walking) was presented. The stimuli varied in contrast and were either intact point-light biological motion, scrambled biological motion, or static body form. Consistent with our previous findings, intact and scrambled biological motion were both detectable at lower contrast than static form, but discrimination of scrambled biological motion required considerably more contrast than discrimination of intact biological motion. Participants were poor at both detecting and discriminating form actions at all contrast levels until the highest. In addition to replicating previous findings, the combination of detection and discrimination into one study provides new details about the information lost between detection and discrimination. We found that even though performance is poorer overall at low contrast in the form condition, there is more information lost between the task of detecting and discriminating scrambled biological motion. Very little information was lost between detection and discrimination for intact biological motion stimuli, indicating that this is highly efficient even at low contrast.

23.429 Domain-specific genetic influence on visual ambiguity resolution Ying Wang[1](wangying@psych.ac.cn), Li Wang[1], Qian Xu[1], Dong Liu[1], Yi Jiang[1]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Psychology, Chinese Academy of Sciences

What we see is seemingly definite, belying the fact that the visual inputs are flooded with ambiguities. Generally, the visual system resolves the ambiguity almost instantaneously, e.g., recognize either the profile or the frontal view of a maiden from a Picasso's painting even before noticing the alternative. By contrast, the perceived content at first glance varies dramatically from one person to another, resulting in idiosyncratic onset bias that challenges the conformity of vision. What drives the discrepancy between individuals in their conscious resolution of the physically ambiguous stimuli? Using a twin method that allows us to identify the determinant of individual difference, we dissociate the role of gene from environment in the process of visual disambiguation. Specifically, monozygotic twins (with identical genes) are more similar than dizygotic twins (sharing 50% genes) in the immediate perception of bistable biological motion but not generic object motion, indicating a domain-specific genetic influence on the way human brain making sense of biological entity. These results challenge the prevalent view that learning-based statistics is the major source of conscious perception, and suggest that part of the disposition of what we turn out to see from relevant yet inconclusive visual information is programmed in the genes.

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23.430 Action prediction and interaction enhances stimulus visibility during binocular rivalry Junzhu su[1](junzhu.su.2011fall@gmail.com), Jeroen J.A. van Boxtel[1], Hongjing Lu[1,2]; [1]Department of Psychology, UCLA, [2]Department of Statistics, UCLA

Humans are able to predict future actions with high temporal precision, and to readily perceive interactions between agents. Previous research suggests that such high-level action inferences influence sensitivity for detecting actions in visual noise (Manera et al., 2011; Neri et al., 2006). We tested whether such top-down influences reached monocular channels to affect the visual dominance of stimuli during binocular rivalry. In Experiment 1, observers viewed point-light action sequences, followed by a blank screen (as temporal occluder) for 200ms or 800ms. Then one eye received a matched action with one color, and the other eye received a mismatched action with a different color. A matched stimlus showed a congruent action as it would have appeared had it continued during the temporal occlusion, and a mismatched stimlus showed an incongruent action that occurred earlier or later than the elapsed time. Observers reported which color was more visually dominant. matched actions were perceived more dominant than mismatched actions in the 200ms occluder condition, but not in the 800ms condition, indicating that the visual system enhances monocular visibility of actions with correct continuations, at least after short delays. In Experiment 2, subjects viewed overlapping actors (one as target and the other as distractor) shown in different colors and in different eyes for ~20s. A third actor, either presented to both eyes or absent, was interactively dancing with the target actor. Observers were asked to continuously track which colored actor (target or distracter) was more visible. When the interactive third actor was shown, the color of the target actor was overall more dominant than that of the distractor actor. This result suggests that interactive information enhances monocular visibility of the actors. Overall, our findings suggest that action inferences can exert top-down influence on low-level visibility of monocularly-presented stimuli during binocular rivalry.

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23.431 **Combining form and motion - an integrated approach for learning biological motion representations** Georg Layher[1](georg.layher@uni-ulm.de), Heiko Neumann[1]; [1]Institute of Neural Information Processing, Ulm University

Recognition of biological motion in primates appears to be effortless even in the case of impoverished input, such as point-light stimuli (PLS; no form; Johansson, Perc. & Psych., 1971) or static implied motion stimuli (no motion; Kourtzi & Kanwisher, J. Cogn. Neurosci., 2000). Recent investigations (Peuskens et al. Eur. J. Neurosci., 2005; Giese & Poggio, Nat. Rev. Neurosci., 2003) support the notion that biological motion is processed in parallel, largely independent form and motion pathways, which are integrated at the intermediate cortical level of STS. None of these models yet successfully explains how missing information in one processing channel can be substituted by the complementary channel and enhance neural activation. We aim at proposing a single integrated model that consists of parallel form and motion processing pathways but incorporates an activity transfer between them. Prototypical form and motion pattern representations (IT/MST) are established using a competitive Hebbian learning scheme. An automatic selection of articulated postures is enabled through motion-form interaction during learning. Convergent temporally correlated input to sequence-selective cells in STS is learned by combined bottom-up and top-down learning (Layher et al., LNCS 7552, 2012). Top-down weights strengthen feedback prediction signals which allow STS neurons to prime afferent cells by expected spatio-temporal signatures. Simulation results obtained using the same previously learned representations are shown for both, implied motion and PLS. Responses of form prototypes to static articulated images drive STS cells which, in turn, send feedback signals to corresponding motion prototype representations, giving a possible explanation for increased fMRI responses in human MT+ to implied motion displays. Likewise, motion pattern prototypes probed with PLS reach activation levels comparable to fully textured animated motion sequences. Here, feedback from STS enhances the activities of corresponding prototype cells in area IT, possibly explaining the activation of form templates during PLS presentation (Lange & Lappe, J. Neurosci., 2006).

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23.433 **Display size of biological motion stimulus influences performance in a complex emotional categorization task.** Ekaterina P. Volkova[1](ekaterina.volkova@tuebingen.mpg.de), Betty J. Mohler[1], Heinrich H. Bülthoff[1,2]; [1]Department of Human Perception, Cognition and Action, MPI for biological Cybernetics, Tübingen, Germany, [2]Department of Brain and Cognitive Engineering, Korea University, Seoul, Korea

People are remarkably good at detecting familiarity with actor (Loula et al., 2005), recognizing the gender (Pollick et al., 2005), emotions (Atkinson et al., 2004) and actions of an actor when presented as biological motion. For many of these tasks the influence of the type of stimuli display (point light display, virtual avatar, full light video) on participants' performance has been well researched (McDonnell et al., 2009). The effect of the size of the display, however, remains underinvestigated. According to our hypothesis, a naturalistic environment and stimuli display would enhance performance, in particular for challenging tasks. We motion captured eight actors, who were asked to portray the following ten emotions while seated: amusement, anger, disgust, fear, joy, pride, relief, sadness, shame, and surprise. The resulting 80 motion sequences were then applied to a stick figure and used for the emotion recognition study. As a between participant factor, the stick figure animations were presented either on a laptop screen or on a large back projection surface. In the latter condition the size of the stick figure matched the natural size of the actors. Thirty-two participants (16 female) took part in a between-subject study (gender balanced). For each stimulus the participant had to make a ten-alternative forced choice to categorize the animation as one of ten emotions. Recognition accuracy was significantly higher for natural size condition (38% accuracy for back projection condition vs. 31% for desktop), and reaction time was lower (2.3 animation repetitions for back projection condition vs. 2.7 for desktop condition). In both conditions the emotional categories were an important factor as some emotions were more easily recognized than others. The results show that for complex tasks, e.g. discrimination among multiple emotional categories, enhanced naturalness of stimuli can be beneficiary for the observer.

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23.434 **The contribution of movement correlation in perceptual judgments of affiliation during social interaction** Nida Latif[1](n.latif@queensu.ca), Kevin Munhall[1,2], Monica Castelhano[1]; [1]Department of Psychology, Queen's University, [2]Department of Otolaryngology, Queen's University

Research in scene perception has demonstrated that humans are able to accurately recognize static visual stimuli with very brief exposures to a scene (Oliva, 2005). This ability is also true of the perception of social information. Very brief exposures or 'thin slices' of behavioral information are sufficient for accurately perceiving properties of social situations. Studies of this phenomena examine how the correlation of movement between two people vary as a result of their affiliation, and how this variation results in accurate perception of affiliation while observing conversation. Coordination of movement is ubiquitously present in social interactions, and this is more prominent when individuals are familiar with each other (Ambady & Rosenthal, 1992; Ng & Dunne). Experiment 1 quantified the variation in how individuals move during conversation based on their affiliation. New methodology using optical flow analysis to quantify motion was used. Results demonstrated that the correlation of movements between friends is significantly greater than the correlation during stranger interaction. Experiment 2 investigated how the perception of this coordination may contribute to accurate judgments of affiliation while observing interaction. We used the previous analysis of movement to examine how correlation serves as a cue for the accurate perception of affiliation by observers. Results demonstrated that although correlation was not a significant cue in affiliation perception, participants could indeed do the perceptual task. We suggest that the perception of social information is multi-faceted and cues may be differentially prioritized based on their availability for perception (i.e. viewing full-body versus facial correlation). These studies also highlight how the visual system may be examined using more complex yet ecologically valid stimuli. Further investigation is being conducted to determine how these visual cues may be perceived and prioritized in specific ways when making accurate social judgments.

Color and light: Material properties

Saturday, May 11, 8:30 am - 12:30 pm

Poster Session, Orchid Ballroom

23.435 **Can you see what you feel? Tactile and visual matching of material properties of fabrics** Bei Xiao[1](beixiao@mit.edu), Xiaodan Jia[1], Edward Adelson[1,2]; [1]Brain and Cognitive Sciences, Massachusettes Institute of Technology, Cambridge, MA, [2]Computer Science and Artificial Intelligence Laboratory, Massachusettes Institute of Technology, Cambridge, MA

Material perception is typically studied by asking for verbal judgments about properties like gloss. But words are limited. When you shop online for clothing, the picture wordlessly conveys haptic information. By looking at the picture you can (hopefully) predict how the fabric will act and feel. The ability to make such predictions is an important benefit of material perception. We selected a pair of fabrics, and presented them both visually ("look but don't touch") or tactilely ("touch but don't look"), and asked the observers to decide which matched which. Since there is a right answer, this allows for an objective assessment of material perception. During each trial, observers were asked to arrange two pieces of fabrics, using their hands (without looking) inside a box to match these to a photograph of the same pair of fabrics displayed on a monitor for 12 seconds. We manipulated the folding conditions and color of the fabrics in the images. In Experiment 1, the fabrics were folded into three conditions: draped over a bumpy object (3D draping), hanging from two adjacent corners (3D hanging), and framed on a flat foam board (2D flat). For each folding condition, 60 pairs of photographs of the fabrics were used. The data show that mean matching accuracy is higher for the 3D conditions than for the 2D conditions. In Experiment 2, grayscale images of the same pairs of fabrics were used for the same shape conditions. We found that removing color reduced matching accuracy, but only for the 3D conditions. Together, our results show that richer visual information, revealing both mechanical structure and texture information, leads to better tactile discrimination in fabrics. Specifically, color and 3D information (such as their draping and deformation properties) are important visual cues for predicting tactile properties of fabrics from images.

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 See page 3 for Abstract Numbering System

23.436 **Visual and Haptic Representations of Material Qualities**

Christiane B. Wiebel[1](Christiane.B.Wiebel@psychol.uni-giessen.de), Elisabeth Baumgartner[1], Karl R. Gegenfurtner[1]; [1]Department of General Psychology, University of Giessen

Material perception research has received considerable attention in the last years. Even though both the visual and the haptic sense play an important role in the everyday perception of materials, the question of how both senses compare in such tasks is unresolved. In a previous study, Bergmann Tiest and Kappers (Acta Psychologica 2007) found a good correspondence between the visual and haptic sense in roughness perception. Here, we set out to investigate the degree of correspondence between the visual and the haptic representations of different materials for a large variety of material properties. We asked subjects to rate 84 different materials for several qualities: Roughness, elasticity, colorfulness, texture, hardness, three-dimensionality, glossiness, friction, orderliness, and temperature. Stimuli consisted of real material samples (14x14 cm in size) that were mounted onto pieces of 12 mm thick medium density fiberboard. Seven different material categories were used for the experiment: plastic, paper, fabric, animal materials (fur and leather), stone, metal and wood. In the haptic condition, subjects were blindfolded and asked to rate the materials based on their tactile exploration. In the visual condition, subjects rated the stimuli based on their visual impressions only. All subjects participated in both tasks. The order of the tasks was balanced between participants. In general, ratings were highly consistent across all 12 participants. Importantly, ratings correlated highly between the visual and the haptic modality (mean correlation: r=0.62 across materials), suggesting similar representations of material qualities in both modalities. This was also revealed by means of a principal components analysis performed on the material property ratings separately for the visual and the haptic task. In both modalities, all material samples were similarly organized within the perceptual space. A subsequent procrustes analysis confirmed that the visual and haptic material space are closely linked and might share a common representational level.

23.437 **Classification of material properties in fMRI**

Elisabeth Baumgartner[1](baumgartnerelisabeth@gmail.com), Christiane B. Wiebel[1], Karl R. Gegenfurtner[1]; [1]Department of General Psychology, Giessen University

The taxonomy of materials has been explored by means of machine classification (Liu et al., IEEE CVPR 2010) and also brain activation (Hiramatsu et al., NeuroImage 2011). Here we wanted to investigate whether information about material qualities like roughness or colorfulness can be found in the BOLD response to material images. We took photographs of 84 material samples and asked subjects to rate them with a seven-point Likert scale on different material qualities: colorfulness, roughness, texturedness, hardness, orderliness, and glossiness. We analyzed the material images according to the algorithm by Portilla and Simoncelli (IJCV 2000). In order to get parameters that grasped the color of our images, we also computed marginal statistics of their components in DKL space. A linear multivariate classifier was applied to the image statistics in order to discriminate between images with high and low ratings. This classification procedure achieved between 69% and 98% correct for the different properties. To see if the information contained in the image statistics would be reflected in brain activation patterns we scanned six subjects with fMRI while they were viewing the material images. A classifier was then applied to the voxel values of visually responsive voxels. We found classification accuracy to be significantly better than chance for three of six material qualities: colorfulness (63%, $p<0.001$), roughness (60%, $p<0.05$), and texturedness (64%, $p<0.001$). Our results demonstrate that information about the qualities of materials is present in the image statistics by Portilla and Simoncelli as well as fMRI activation patterns. In addition, we checked if the classification accuracy of the image statistics classifier would improve using the labels given by the fMRI classifier. At least for roughness, this was the case (69% vs 74%, $p<0.05$). This suggests that there might be a link between the observed brain activation and the image statistics.

23.438 **The perception of gloss in natural images**

Karl Gegenfurtner[1](gegenfurtner@psychol.uni-giessen.de), Elisabeth Baumgartner[1], Christiane Wiebel[1]; [1]Abteilung Allgemeine Psychologie, Giessen University

It has been suggested that the perception of gloss in natural material images is strongly related to the skewness of the luminance histogram (Motoyoshi et al., Nature, 2007). Here, we set out to evaluate the validity of this findings in a large and diverse material image dataset of 1492 images. The images were chosen from several material image databases, encompassing 10 different material categories. 8 subjects were asked to categorize each briefly (33 ms) presented image as either glossy or matte by the press of a button, or, if undecided, not give an answer at all. Subjects were encouraged to respond as quickly as possible. Only responses given within 500 ms were taken account. Images were sorted according to the degree of consistency with which they were assigned to one of the two groups. 76 images were consistently rated as matte, and 112 images were consistently rated as glossy by all 8 observers. Crucially, we found the two sets of images to be significantly different, with glossy images being substantially more positively skewed. Images could correctly be classified as "glossy" or "matte" with an accuracy of 75% based on the skewness parameter. This difference became systematically smaller when we considered images with ratings of decreasing consistency. Our results agree with earlier findings by Motoyoshi et al (Nature, 2007) and Anderson & Kim (Journal of Vision, 2009). Even in a very large and varied stimulus set, glossiness and skewness are associated. However, skewness alone is not sufficient to induce the percept of gloss in each single image.

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23.439 **Lightness perception for glossy objects**

Matteo Toscani[1](Matteo.Toscani@Psychol.uni-giessen.de), Matteo Valsecchi[1], Karl Gegenfurtner[1]; [1]University of Giessen

The presence of gloss on the surface of objects is a challenge for the visual system when trying to recover their color (Xiao and Brainard, 2008). Here we test how humans deal with glossy objects for judging their lightness. Observers were presented with two rendered images of golf balls and had to judge which one had a lighter surface. The balls could be either glossy or matt. One of the two objects had a constant reference reflectance while the reflectance of the other one was varied in nine steps. The slopes of the discrimination curves were shallower (by more than a factor of 2) for the glossy objects, indicating lower performance. We observed previously (Toscani,Valsecchi and Gegenfurtner, VSS 2011) that observers fixated the brightest parts of matte objects when performing a similar task. Using a physically based rendering simulation we demonstrated that for matt objects the diagnostic value of image pixels about the objects' reflectance increased monotonically with their luminance. For glossy objects, however, the brightest pixels are of course not informative of the objects' reflectance. In order to investigate whether observers behaved accordingly, we recorded their eye movements while doing the task. Consistent with the results of the simulation, observers had a tendency not to look at the specular highlights when asked to judge the lightness of glossy objects. In contrast, a bottom up saliency approach (Itti and Koch, 2000) applied to our glossy objects predicted that the highlights should be preferentially fixated. In summary, the data we collected from glossy objects show that observers sample the most informative parts of objects for making lightness judgments. They use an optimal strategy without being distracted by the highly salient but less informative specular highlights.

23.440 **Characterization of high-level images features for surface gloss perception**

Qin Wang[1](qinwang@gmail.com), Isamu Motoyoshi[1], Shin'ya Nishida[1]; [1]NTT Communication Science Laboratories, NTT

Effective cues for surface gloss perception reside in low-level image statistics, including skewness of luminance or subband histogram (Motoyoshi, Nishida, Sharan & Adelson, 2007). It is also suggested that gloss perception is modulated by high-level spatial information such as consistency between patterns of specular highlight and diffuse shading (Anderson & Kim, 2009). To gain further insight into the nature and the processing mechanism of high-level gloss features, we examined the effects of highlight consistency, peripheral viewing and texture synthesis on gloss perception. The stimulus we used was a surface modulated in depth by a low-pass-filtered random field and rendered by the Ward illumination model. We made a highlight-consistent image by combining specular and diffuse patterns made from the same depth profile, and a highlight inconsistent image by combining specular and diffuse patterns made from different uncorrelated depth profiles. Using the algorithm by Portilla & Simoncelli (2000), we also synthesized two types of texture image each sharing low-level image statistical measurements with the highlight-consistent and highlight-inconsistent surface images, respectively. We used a magnitude rating, and a pairwise magnitude comparison, to evaluate gloss perception for these images. The results indicate that highlight-consistent surfaces looked much more glossy than highlight-inconsistent surfaces when viewed in the fovea, but this difference was reduced as the retinal eccentricity was increased. Synthesized textures did not look glossy at any eccentricity, and it was hard to discriminate highlight-consistent textures from inconsistent ones. Our findings suggest that critical image features that produce the apparent gloss difference between highlight-consistent and inconsistent images are available to human observers mainly through foveal vision, and that these features cannot be captured by the image statistics preserved by the Portilla & Simoncelli algorithm.

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23.441 An fMRI Study of Cortical Responses for Reflectance-specific Image Motion

Tae-Eui Kam[1](kamte@korea.ac.kr), Damien Mannion[2,3], Seong-Whan Lee[3], Katja Doerschner[4,5], Daniel Kersten[2,3]; [1]Department of Computer Science and Engineering, Korea University, Seoul 136-713, Korea, [2]Department of Psychology, University of Minnesota, [3]Department of Brain and Cognitive Engineering, Korea University, [4]Department of Psychology, Bilkent University, Ankara, Turkey, [5]National Magnetic Resonance Research Center (UMRAM), Ankara, Turkey

Competent visual behavior depends on the accurate perception of the shape and material of objects in the world. These perceptual decisions can be informed by the neural processing of high-dimensional motion flow patterns that begin at the retina and continue through several cortical areas. While we have a reasonable understanding of the computational, perceptual and neural basis of shape from motion flow, we know relatively little of how the visual system infers material from motion. Recently, we discovered several surface reflectance-specific motion characteristics that the visual system may use to determine whether a rotating object appears shiny or matte (Doerschner et al., Current Biology, 2011). We are now using neuroimaging to look for the neural basis of material-specific motion flows. To this end, we have designed an experiment to test whether neural responses to patterns of object surface motion flow that distinguish shiny from matte surfaces can be localized to particular brain regions. Stimuli were computer-rendered movies of 5 unfamiliar, rotating objects with 'sticky' (diffusely reflecting) and 'slipping' (100% specularly reflecting) conditions (image flow) and their dot flow patterns, the latter calculated by a phase-based optical flow method (Gautama et al., 2002). We set the retinotopic visual areas and the human motion complex (hMT+) as primary regions of interest and measured BOLD signals at 3T (n=6). We found that responses in V1, V2, V3, hV4, and hMT+ were significantly higher for shiny than matte motion (all $p < 0.05$). Such differences were present for both images and dot flows, with the exception of hV4 where it was only observed for images.

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23.442 Effects of retinal-image motion of specular highlights induced by object motion and manual control on glossiness perception.

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Specular highlights on an object under stationary lights move when an observer and/or the object moves. The valid retinal-image motion of highlights enhances percept of gloss (Hartung & Kersten, VSS 2002), and it is further improved when the image motion is induced by observer's voluntary head motion (Araki, et al., APCV 2011; Tani et al., under review). Active manual control facilitates some aspects of visual cognition (eg, object recognition: Harman, et al., Current Biology 1999, temporal vision: Ichikawa & Masakura, Vision Research 2006). We aimed to test whether the retinal-image motion induced by active manipulation of the object further improves glossiness perception. One of five bumpy spheres (15deg diameter) with different specular reflectance (30-50%) was presented for 4s a trial. The average luminance of all spheres was equalized by adjusting diffuse reflectance. The sphere was either stationary or rotated back and forth for 60deg at 0.25Hz on a CRT display (retinal-image motion). Nine participants observed it while they held a ball either with or without manual motion, which was monitored by a motion tracker at 85Hz. In the condition with the retinal-image motion and manual motion, sphere's retinal-image motion was accurately synchronized with participant's hand motion (manual control). Participants were asked to rate sphere's glossiness using visual-analog scale. They performed 16 repetitions of combinations of 2 retinal-image-motion conditions, 2 manual-motion conditions and 5 specular-reflectance conditions in random orders. We found that the perceived glossiness was significantly higher and response variance was smaller with retinal-image motions than without them. However, manual control did not further improve the perceived glossiness. A subsequent experiment (n=8) using low specular reflectance (5-31%) also did not show additional effects of manual control. These results suggest that the valid retinal-image motion of highlights enhances the perceived glossiness and its reliability regardless of whether it is caused by voluntary action.

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23.443 Two kinds of perceptual surface qualities: Temporal properties of surface quality perception

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Though we can discriminate different material categories (e.g., metal, fabric, glass, etc.) at a glance, perceptual surface qualities (e.g., glossiness, transparency, texture, etc.) effective for the material category discrimination are unclear. We investigated the effects of stimulus durations on a material discrimination task and surface quality judgment tasks to know the relationship between perceptual surface qualities and material discrimination. In the experiments, the observers were presented with two object images with an identical three-dimensional shape but made of different materials from seven categories (metal, plastic, glass, stone, wood, leather and fabric) for 30 ~ 100 ms. They performed two kinds of tasks after the stimulus presentation: a material discrimination task and surface quality judgment tasks. In the material discrimination task, they responded if the material categories of the two objects were the same or not. In the surface quality judgment tasks, they responded which of the two objects was more glossy, rougher, or heavier (glossiness, roughness, and heaviness tasks, respectively). First, the performance of all the tasks increased with the stimulus duration as expected. However, the increase rate was much lower for the heaviness tasks than the other two surface quality tasks, even when the task difficulties were equalized between the three tasks. Second, the correlation between the performance of the material discrimination task and perceptual scores for different surface qualities measured in another experiment increased with the stimulus duration for glossiness and roughness scores, but not for heaviness scores at all. These temporal properties of surface quality perception suggest at least two kinds of surface qualities: one quickly processed and utilized for higher-order material perception (e.g., material categorization), and the other slowly processed and not utilized for higher-order material perception. The latter might be derived only via top-down processes from material recognition.

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23.444 Constituents of material property perception

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We have previously introduced frequency-band based analyses as an approach to infer material properties like roughness, thickness, and volume from images of fabrics (Giesel & Zaidi, Frequency based perception of material properties, Current Biology, under review). Here, we address how these material properties and their frequency-band representations are influenced by viewing parameters such as the distance or angle, and the illumination direction. To determine whether the viewing distance has an influence on the perception of material properties, we varied it by using two CRTs. The reference monitor was placed at a distance of 66cm, while the comparison monitor was placed at 33, 66, or 132cm. The original stimulus was displayed on the comparison monitor, while either the original or one of four manipulated versions of the original image was shown on the reference monitor. The observers' task was to indicate which of the images of a fabric displayed on the two monitors appeared as having more volume, as being thicker, or rougher, respectively. The results showed that over the tested range of viewing distances the perception of material properties remained largely constant indicating that the visual inference of material properties is more likely to be based on estimated material spatial frequency than on retinal frequency. We complemented the psychophysical results by image analyses using images from the KTH-TIPS database containing images of materials photographed at different distances, slants, and illumination directions. We show that the changes in material appearance are closely reflected in the frequency-band signatures. Finally, we present results from an experiment in which observers ranked printed versions of fabric images according to their volume, thickness, and roughness. We show that observers' ratings were closely correlated with amplitudes in the three frequency bands we identified previously.

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23.445 **Material from motion — Human perception of fluid properties from motion vector fields.** Kazushi Maruya[1](kazushi.maruya@gmail.com), Takahiro Kawabe[1], Shin'ya Nishida[1]; [1]NTT Communication Science Laboratories, Nippon Telegraph and Telephone corporation

Viscosity is a material property that is unique to fluid. In physics, viscosity is described as a parameter for the motion of fluid. This means that motion information should contain information of viscosity. In psychophysics, human observers can veridically estimate fluid viscosity just by looking (Kawabe et al., 2012, VSS; Fleming et al., 2012, VSS). Can the visual system estimate fluid viscosity solely from motion information? To examine this question, we created a novel motion stimulus, called the simulated motion field (SMF), which consisted of an array of patches. The carrier pattern of each patch was a low-pass filtered white noise, and moved within a stationary circular envelope. The array of carrier movements simulated optical flow patterns extracted from CG animations of scenes including moving liquids. We obtained the following results. (a) SMF gave observers a vivid impression of dynamic liquid. (b) In accordance with an increase in the kinetic viscosity of the original CG animation, the viscosity rating was increased for SMF, although the slope halved relative to the rating for the original CGs. (c) A primary cue for viscosity was local image speed — an SMF looked less viscous just by increasing local speeds. (d) From the original SMFs containing spatiotemporal variations of local motion vectors, we made SMFs containing only spatial variations, and those containing only temporal variations. Liquidness rating for the spatial SMF was comparable to that for spatiotemporal SMF, but the rating for temporal SMF was significantly lower. Viscosity rating followed the simulated viscosity for spatial SMFs, but not for temporal SMFs. These results indicates that the human visual system can perceive the material property of moving fluid from optical flow information alone, and that the critical information resides in the local flow speed and spatial pattern of the optical flow field.

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23.446 **Seeing transparent liquids from dynamic image distortion** Takahiro Kawabe[1](kawabe.takahiro@lab.ntt.co.jp), Kazushi Maruya[1], Shin'ya Nishida[1]; [1]Human Information Science Laboratory, NTT Communication Science Laboratories, Nippon Telegraph and Telephone Corporation

How can the human observer perceive transparent liquid? Transparent liquid often causes a distortion of an image below it due to refraction at the non-flat surface of the liquid. In accordance with non-rigid motion of the liquid surface, the pattern of image distortion dynamically changes. It is possible that the visual system interprets the dynamic image distortion not as a mere change in image, but as a dynamic distortion of a stable bottom image caused by the intervention of a transparent liquid. We therefore examined whether and how the visual system utilized dynamic image distortions as a cue for discerning a transparent liquid. We created computer graphics movies that simulate scenes in which a unidirectional flow of a transparent liquid, with the refraction index of water (1.33), ran in front of a variety of texture backgrounds. We removed specular reflection at the liquid surface to test the pure effect of image distortion. A rating experiment indicated that a strong impression of a transparent liquid was obtained with the movies. However, this impression collapsed either with a single static movie frame or with the movies presented with blank intervals of 100 msec between frames. These results indicate that the visual system can utilize the dynamic change in image distortion as a cue to discerning a transparent liquid. Indeed, a transparent liquid was perceived only by a dynamic random deformation of an image that had deformation statistics similar to the fluid movies. Further experiments clarified that the dynamic change of the coarse (4-16 cycles per image) image distortion had to be presented for approximately 200 msec to produce the strong impression of a transparent liquid. The results indicate that the temporal pooling of the spatially coarse image distortions underlies the perception of a transparent liquid.

Acknowledgement: This work was supported by KAKENHI (Grant-in-Aid for Scientific Research on Innovative Areas No. 22135004)

23.447 **Experts and novices use same factors but different way to grade pearls** Yusuke Tani[1](tani@vpac.cs.tut.ac.jp), Takehiro Nagai[1], Kowa Koida[2], Michiteru Kitazaki[1], Shigeki Nakauchi[1]; [1]Department of Computer Science and Engineering, Toyohashi University of Technology, [2]Electronics-Inspired Interdisciplinary Research Institute, Toyohashi University of Technology

Pearls are graded by experts according to their shape, glossiness, and structural color. Although we have attempted to reveal how novices grade pearls (Kato et al., ECVP 2011), it is still unknown. The aim of this study is to investigate the reproducibility of experts' grading and to compare the experts' grading and novices' grading. Eight experts and six novices participated in the experiment. The task was to grade ten size-controlled pearls, which were labeled by other experts, who did not participate in the experiment. We used two sets of pearls for experts and two or three sets for novices. Experts graded five times for each set, and novices graded ten times for each set alternately. Novices were not given any instruction about how pearls should be graded. We found that the reproducibility of experts' grading was higher than that of novices' grading, but novices' reproducibility was enough higher than the chance. The correlation between novices' grading and labeled rank was as high as the correlation between experts' grading and labeled rank. But we found the difference between them in the results of multiple regression analysis in which the measured values of glossiness and structural color were used as independent variables and the grade was set as dependent variable. Although all novices had significant trials, which could be explained by the linear regression function, there were only three experts who had such trials. This could be interpreted that novices without knowledge about how to grade pearls could make use of these two factors simply and that experts used them in a complex manner, because experts also ought to rely on these two factors to grade pearls. These results would suggest that people, at least Japanese people, inherently have a nature to be fascinated by the glossiness and structural color of pearl.

Acknowledgement: Grant-In-Aid for Scientific Research on Innovative Areas #22135005

Saturday AM

3D perception: Space

Saturday, May 11, 8:30 am - 12:30 pm

Poster Session, Orchid Ballroom

23.448 **Naturalistic Depth Perception: Spatial Vision Out The Window** Brian C. McCann[1](brian.c.mccann@utexas.edu), Mary M. Hayhoe[1], Wilson S. Geisler[1]; [1]Department of Psychology and Center for Perceptual Systems, University of Texas at Austin

The traditional approach in studying depth perception is to measure and model performance for simple stimuli containing just one or two maximally isolated depth cues. While this approach has proven informative, it is incomplete. Visual systems are presumably optimized for recovering depth from complex natural stimuli by simultaneously combining many depth cues. Thus, observers are likely sensitive to the rich and sometimes counter-intuitive correlations between features in natural images. This sensitivity could both facilitate and hinder performance when discriminating simple stimuli lacking this natural structure. These considerations motivated us to pursue a complementary approach in which stimuli begin rich with naturalistic variation and experimental control is achieved through systematically applied constraints. Here we present critical baseline measurements of human depth discrimination in "cue-complete" scenes. Using a robotically positioned laser range finder coupled with a calibrated DSLR camera, we collect stereoscopic natural images that are precisely co-registered with pixel-wise range data. These images are cropped to be geometrically consistent with viewing from the camera's positions through a simulated window. That is, an active stereoscopic projection approximately 1.5m wide, 0.5m high, and 3m away (with 60mm separation). Note that depths so large are unlikely to generate large conflicts between vergence and accommodation, nor are the patterns of defocus likely to substantially differ from natural viewing. Observers judged the nearer of two indicated locations falling on objects within the scene. Both fixation and response time were unconstrained. Conditions were parametrically and fully sampled along three dimensions: (i) the observer's distance to the nearer point, (ii) the visual angle separating the two points, and (iii) the difference in distances to the two points. Extensive data collected on an author judging thousands of locations in a preliminary set of 10 stereo images suggests that accuracy across the space can be well described with only three parameters.

23.449 **Postural Sway is Affected by Visually Perceived Geographical Slant** Alen Hajnal[1](alen.hajnal@usm.edu), Deanna Rumble[2], John F. Shelley-Tremblay[2], Wei Liu[3]; [1]Department of Psychology, University of Southern Mississippi, [2]Department of Psychology, University of South Alabama, [3]Department of Physical Therapy, University of South Alabama

Past research has shown that visual inspection of nearby targets is tied to more stable posture during quiet stance (Bonnet, Temprado, & Berton, 2010). The current study seeks to answer an even more basic question, namely, how ground surface inclination (geographical slant) influences postural stability. The present contribution shows that perceived geographical slant may significantly influence postural stability even in the absence of definite visual targets. In two experiments participants stood on a force

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platform that measured center of pressure (COP) during quiet stance while looking at a rigid surface of varying geographical slants. Using an otherwise identical procedure, participants in the second experiment also provided verbal estimates of the steepness of the surface in degrees. Several measures of postural stability offered converging evidence that postural sway gradually increased as geographical slant decreased to zero (horizontal ground). Specifically, the anterior-posterior component (y-coordinate) of COP was sensitive to changes in surface slant. Both the range and the standard deviation of COPy showed the same statistically significant trend of increased variability with decreasing slant angles in both experiments. The area of the ellipse covering COP sway (based on a principal components analysis) showed the same tendency: ellipse area got larger for smaller slants. Finally, the nonlinear fractal dynamics of postural sway, as measured by the Hurst exponent of COPy pointed in the same direction: more fractal patterns, known to be correlated with increased muscle activity and decline in postural stability were measured for shallower surface slants. There were no effects of Experiment in any of the measures, suggesting that explicit perception (verbal estimation) of slant does not bias postural stability above and beyond the effects of visual environment. Future studies are planned to tease apart the implicit effects of distance and slant to gauge the overall contribution of visual environment to postural stability.

23.450 **The Scaling of Outdoor Space in Tilted Observers** Brennan Klein[1](bklein2@swarthmore.edu), Daniela Jaeger[1], Zhi Li[1], Ariana Spiegel[1], Frank Durgin[1]; [1]Department of Psychology, Swarthmore College

Perceptual matches between vertical extents (poles) and egocentric extents (between the observer and the pole) show that observers set themselves much too far from the pole, consistent with an under-perception of egocentric distance (Li, Phillips & Durgin, 2010). These matches can be modeled by assuming that angular gaze declination is exaggerated with a pitch-angle gain of 1.5. Matches to horizontal frontal extents suggest a lesser yaw-angle gain of about 1.2 (Li et al., in press). We tested whether angular biases in space perception were affected by observer orientation relative to vertical. Observers (96) were tested in four, between-subject conditions: (1) Walking, (2) Sitting upright on a cart, (3) Lying sideways on a cart (tilted 90° from vertical), and (4) Lying at an oblique angle (54° from vertical) on a cart. Each observer made three judgments: one egocentric matching judgment to a 10 m vertical pole (half started near; half far and adjusted themselves to be in the apparent match location), one 45° gaze elevation judgment to a 35 m tower (half started near; half far and adjusted themselves to be at an apparent 45° to the top of the tower), and one verbal height estimate of the 35 m tower. Upright observers and tilted observers showed similarly biased matches between egocentric distance and object height and consistently biased apparent 45° gaze setting, consistent with the model proposed by Li et al. (2010). This suggests that exaggerations of gaze elevation and declination are referenced to the world rather than the body. However, tilted observers gave reliably lower verbal estimates of tower height (geometric mean: 28 m), than did upright observers (45 m). Although eye-height was similar across conditions, it may have been underestimated in the tilted conditions -- which should reduce height estimates proportionally but not affect matching.

Acknowledgement: NIH R15EY021026

23.451 **Perceived aspect ratio on tilted surfaces supports the hypothesis that perceived slant approximates a scaled sine function of actual slant** Zhi Li[1](zhi.li.sh@gmail.com), Frank Durgin[1]; [1]Psychology Department, Swarthmore College

It has long been known that the perceived aspect ratio of two perpendicular extents is not veridical – especially when one of the extents is shown in depth. Recent work conducted in high fidelity virtual reality (VR) suggested that bias in perceived aspect ratio is strongly correlated to bias in perceived slant, on which the aspect ratio stimuli is presented (Li and Durgin, 2010). In the present study, two experiments were conducted in VR to extend this previous finding. In the first experiment, the perceived aspect ratio of an L-shaped arrangement of balls on slants from 9° to 90° was measured. Two viewing distances (2 m and 8 m) and two types of slants (pitch slant and yaw slant) were used. The bias for the yaw slant was found to be systematically larger than that for the pitch slant, but this difference could be attributed to a vertical horizontal illusion. For both types of slant, the bias in the perceived aspect ratio increased with viewing distance. In the second experiment, bias of perceived aspect ratio was examined with slants from 6° to 24° (to test for a range effect), and the texture was either scaled or not scaled with viewing distance in two groups of subject. There was weak evidence of a range effect on perceived slant, but the changed scaling of texture with distance did have a reliable influence on aspect ratio judgments. Overall, the results of the present study can be quantitatively explained by assuming that the perceived slant function is a scaled sine function of the simulated slant, which is consistent with the verbal estimation data of real slants within reachable distance (Durgin, Li and Hajnal, 2010).

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23.452 **Cast-body shadows compress perceived distances** Christopher Kuylen[1](christopher.kuylen@gmail.com), Laura Thomas[1], Ben Balas[1]; [1]Psychology, North Dakota State University

When people use a tool to interact with a distant object, the tool can serve as an extension of the human body, leading observers to perceive the object as significantly closer to them (e.g., Davoli et al., 2012). Another entity that may function as an extension of the human body is the cast-body shadow. Although observers cannot use shadows to manipulate objects, they do extend from an observer's body and create visual changes in the area beyond peripersonal space. We investigated the influence of cast-body shadows on distance perception. Participants (N = 9) viewed an athletic cone at one of eight randomized distances (20'-55') in three experimental conditions: (1) while shining a laser pointer on the athletic cone, (2) while a light projected their cast-body shadow towards the athletic cone, (3) and under a control condition. Participants then estimated the distance to the cone by turning away, watching the experimenter walk, and telling the experimenter to stop when they thought he was the same distance away as the previously viewed athletic cone. Participants' distance estimations of the cone were significantly shorter in both the laser and shadow conditions than in the control condition ($p<0.005$ in each case), but the laser and shadow conditions did not differ from each other ($p=0.50$). This demonstrates that, like tools, shadows serve as an extension of the body, leading to an underestimation of perceived distance. The results add new support to the hypothesis that extensions of the human body can perceptually distort space and indicate that cast-body shadows are perceived as part of the observer's body representation and may thus influence a wider range of perceptual phenomena.

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23.453 **The taller you are, the smaller the world appears: perceptual distortion of binocular space depends on the size of personal body space** Amanda Lee[1](amanda_lee_1@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

It has been theorized that our body serves as a reference frame in visual perception of sizes and distances. In support of this claim, indirect experimental evidence shows that induced modification of peripersonal space, for example through tool use (Witt, Profitt, and Epstein, 2005) or ownership of magnified/shrunken body parts (van der Hoort, Guterstam, and Ehrsson, 2011), results in modified perception of objects size or egocentric distances. However, direct measures in support of this hypothesis was previously lacking; here we found that scaling of depth from stereo depends on the size of the peripersonal space by testing disparity scaling directly with short and tall observers (corresponding to smaller and larger peripersonal space respectively), without manipulating subject's perceived personal space. Participants adjusted the depth of a virtual 3D three-rod configuration, in which one central rod was offset in front of two flanking rods, until they perceived a perfect equilateral triangle. Stimuli in this visual depth estimation task were presented in the dark such that stereo cues were isolated. Simulated distance of the stimulus was randomly generated from five possible values (28cm, 46cm, 64cm, 82cm and 100cm). The results were grouped according to height (SHORT: $150<h<160$ cm and TALL: $173<h<190$ cm). As expected, all subjects demonstrated a lack of shape constancy, as perceived depth of the three-rod configuration decreased with increased distance. More remarkably, findings showed that short observers perceive larger depth extents than tall observers ($p<0.03$), indicating that scaling distances of tall observers were smaller than those of short observers. These results suggest that scaling of disparities is dependent on the extent of peripersonal space; indeed, this implies that scaling distances within the same external space are more compressed for people with larger body morphologies.

Acknowledgement: NSF #BCS0643234

23.454 **Influence of shape on stabilization of ambiguous structure from motion** Ken Sobel[1](k.sobel@mac.com), Amrita Puri[2]; [1]Department of Psychology and Counseling, University of Central Arkansas, [2]Department of Psychology, Hendrix College

Fang & He (2004) used stereoptical depth cues to make the upper and lower thirds of a rotating structure-from-motion cylinder appear to rotate in a single direction. Although the middle section of the cylinder had

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zero disparity, its rotation direction was stabilized, appearing to rotate in the same direction as the two ends. Adaptation to the stabilized middle section generated a motion aftereffect, inducing a subsequently viewed ambiguous cylinder to appear to rotate in the opposite direction. We asked whether stabilization of the ambiguous middle section occurred merely because it was situated between two rotating objects, or if the shape of the stimulus implied that the three sections were part of the same object. To answer this question, we used more complex shapes than a cylinder to more strongly imply that the middle section fits between the two ends. During adaptation observers viewed one of three rotating shapes (a cylinder, sphere, or cylinder that tapered towards the top). The upper and lower third of each adapting shape consisted of dots drifting in just one direction as if that part of the shape were opaque. In the middle third dots drifted in both directions as if scattered across a transparent object. After 60 seconds the upper and lower thirds disappeared and the middle section continued rotating for 15 seconds, during which observers indicated the apparent rotation direction with key presses. Contrary to our expectations, adaptation was stronger (as indicated by longer rotation duration in the direction opposite to adapting rotation) for the cylinder than for either of the two other shapes. One possible explanation for these results is that the cylinder spanned a larger visual angle than the other shapes so it may have had more stimulus energy than the other shapes.

23.455 **The Roles for Angular Declination and Gaze Direction in the Fast Extraction of Distance** Daniel A. Gajewski[1](gajewsk1@gwu.edu), Courtney P. Wallin[1], John W. Philbeck[1]; [1]Department of Psychology, The George Washington University

Humans can walk without vision to previewed targets (2.5-5 m distant) without large systematic error and with near perfect sensitivity to target distance, even when targets are briefly glimpsed. However, high levels of performance with brief viewing durations are observed primarily with floor-level targets, where the angular direction of the target provides a reliable source of information about distance. The present study determined the roles for visual cues (angular declination) and ocular cues associated with gaze direction in the extraction of distance to briefly viewed targets. In Experiment 1, an eyetracker was employed with a variable fixation point to ensure gaze was directed toward the target on every trial. The viewing duration was either brief (approximately 19 ms, based on a detection threshold procedure) and followed by a mask or participants saw only the mask. In the latter case, participants were led to believe the viewing duration was below threshold and were instructed to estimate distance to unseen floor-level targets based on the knowledge that they were looking directly at the object at the onset of the trial. Surprisingly, participants responses were more sensitive (slope = 1.06 versus 0.84) and less biased (-17% versus -22%) when they reported not seeing the object. In Experiment 2, distance estimates based purely on gaze direction were less precise but not less accurate than those observed in Experiment 1. Experiments 3 and 4 compared performance for briefly viewed targets as a function of target eccentricity at the moment of the glimpse. Peripheral targets were not less accurately localized than those that were directly fixated. The overall pattern of results suggests a dominant role for angular declination in the localization of briefly viewed targets regardless of gaze direction but also a role for ocular cues that does not depend on the availability of visual cues.

Acknowledgement: NIH Grant R01EY021771 to John W. Philbeck

23.456 **The Impact of Occluded Surfaces on Absolute Distance Judgments in Room Environments** Courtney P. Wallin[1](courtneypwallin@gmail.com), Daniel A. Gajewski[1], John W. Philbeck[1]; [1]The George Washington University

When viewing durations are as brief as 100ms, humans can estimate the distance to floor-level targets with great sensitivity (slopes near 1) and a slight bias toward underestimation. Such bias disappears as glimpses are extended, presumably affording eye movements to successfully extract and sequentially integrate local ground information. Recent eye tracking data has revealed no effect of eye movements on one's ability to make distance judgments during long viewing durations, however. We conducted two experiments to confirm a crucial role for surface information that presumably must be extracted even in the absence of eye movements. All subjects were exposed to both an occluded and a full-viewing condition with block order manipulated. Subjects were instructed to hold gaze on the object once fixated for the duration of the trial (5 seconds) and judged distance via blind-walking to targets 3-6 m distant. In Experiment 1, the occluder obstructed ground surface between observer and target. There was a modest effect of occlusion on sensitivity but only when the occluded condition preceded the full-viewing condition (slope = 0.85 versus 1.01). Indoor environments contain other surfaces (walls and ceiling) which may bias distance judgments when local ground patches are obscured. In Experiment 2, participants viewed the room through a pair of goggles with a small (~ 15o) square aperture. Such a restricted field of view profoundly limited potentially informative cues, leading to lower sensitivity and greater bias towards underestimation when the aperture condition preceded the full-viewing condition (slope= 0.74 versus 1.09). There was no effect on sensitivity when the full-viewing condition preceded occlusion. The results suggest that the nearby ground plane is not as crucial in indoor environments, presumably because other surfaces provide similar reference frames. Additionally, these sources of information need not be extracted with eye movements necessarily– covert deployments of attention are sufficient.

Acknowledgement: NIH 1R01EYO21771-01 to John W. Philbeck

23.457 **Viewpoint Independence in Implicit Scene Learning** Zhongting Wang[1](virtualsun@hotmail.com), Shiyi Li[1], Haibo Yang[1], Deli Shen[1], Xuejun Bai[1], Hong-jin Sun[2]; [1]Academy of Psychology and Behavior,Tianjin Normal University,-Tianjin,China, [2]Department of Psychology, Neuroscience & Behaviour, McMaster University, Canada

It has been well established that repeated configurations of random elements induce better search performance than that of the displays of novel random configurations (contextual cueing effect). However, whether spatial learning can be transferred to a different viewpoint of a 3D scene has not been well studied. In this study we examined search behavior in a computer rendered illustration of a realistic scene. Participants viewed the scene (with the viewpoint at 30 degrees above the ground) consisted of an array of chairs randomly positioned on the ground. Observers were presented with a sequence of trials in which they searched for and identified an arbitrarily located target letter positioned on the surface of the seat of the chair. In the training session, participants completed 20 blocks of 16 search trials. Eight of the trials in each block were in the repeated condition where a particular target location was consistently paired with a particular array. The other 8 trials were in the novel condition, where a target was presented on a chair within a randomly generated search array. The training session was followed by a transfer session of 5 blocks, in which the viewpoints of the scene were rotated for 40 degrees on the ground plane. Significant contextual cuing was found in the training session, with faster RTs in the repeated condition than in the novel condition as participants learned the relationship between repeated layout and target location. Contextual cuing with comparable magnitude was also found after the change of viewpoint, suggesting view-independent representation of the scene. Contrary to viewpoint dependency found by Chua and Chun (2003), our results suggest that when the scene contained clear indication of the view change (from ground texture and individual chairs), the spatial relation learned during training can be mentally transformed to a new viewpoint.

Acknowledgement: The Ministry of Education of China & NSERC

23.458 **Effects of magnification on depth perception and visually-guided reaching** Bing Wu[1](Bing.Wu@asu.edu), Roberta Klatzky[2], John Galeotti[3]; [1]Cognitive Science & Engineering Program, Arizona State University, [2]Dept. of Psychology, Carnegie Mellon University , [3]Robotics Institute, Carnegie Mellon University

Previous experiments and computational analysis have shown that optical magnification not only changes the content of visual depth cues like texture gradients and binocular disparity (Purdy, 1960; Lumsden 1980), but also affects the availability of some cues (Du et al., 2001). How, then, are these depth cues combined and how is their relative effectiveness changed by magnification? Most previous research examined the perception of depth in action space and focused mainly on pictorial cues. The current study investigated the effects of magnification on spatial perception and guided action within arm's reach under microscope. In two experiments, magnification was optically created using a low-power stereoscopic microscope. The subjects looked through the microscope (magnification power of 1.05x, 3.5x, and 5.0x, or naked eyes) with one or two eyes (monocular vs. binocular), and compared the relative depth between two targets (Experiment 1) or directed a stylus from a starting point to a target (Experiment 2). In Experiment 1, the consequences of magnification for the accuracy of relative depth judgments were assessed using a matching task. Under binocular viewing, matching error was found to increase with magnification and to be lowest with the naked eye. In contrast, performance improved with magnification under monocular viewing. In Experiment 2, where performance in a reaching task was tracked and analyzed, similar patterns were observed for action responses. The results suggest that changes in depth cues induced by magnification, particularly decreased effective range of distance and increased demands on accommodation, result in differential utilization of accommodation and binocular cues.

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23.459 **Expression of a 3D size illusion in the C1 component of ERPs** Yang Zhang[1](zhangyang873@gmail.com), Yang Sun[1,2], Fang Fang[3], Ming Zhang[1]; [1]Department of psychology, Northeast Normal University, China , [2]Department of Psychology, Tsinghua University, China , [3]Department of Psychology, Peking University, Beijing, China

Size perception in a 3D scene is known to be affected by distance perception. Two objects with the same physical size appear to have very different sizes if they are perceived to be at different distances. The primary visual cortex area (V1) has been demonstrated to be a critical area to process the 3D size illusion. However, when the representation of the size illusion starts to manifest in V1 remains largely unknown. Here we used the methods of psychophysics and event-related potentials (ERPs) to investigate the time course of brain activity related to the size illusion processing. Psychophysically, we measured the magnitude of the 3D size illusion by asking participates to adjust the size of a ball on a uniform background to match the perceived size of a ball (either near or far) in a 3D scene. The perceived size of the far ball was larger than that of the near ball. Electrophysiologically, we acquired EEG data while participates were asked to detect a small dot occurred on the balls with a small probability (20% of trials). We manipulated the position and contrast of the ball to construct four experimental conditions (high contrast far, low contrast far, high contrast near and low contrast near condition), which enabled us to isolate the ERPs for the balls only by subtracting the ERPs elicited by the low contrast stimuli from those elicited by the corresponding high contrast stimuli. We focused on the earliest visual ERP component C1 that normally peaked around 80 ms post-stimulus onset and has been demonstrated to originate in V1. We observed a significantly greater amplitude of C1 in the far condition than the near condition. These results suggest that the V1 area starts to represent the 3D size illusion as early as less than 100 ms.

Attention: Neural mechanisms and models

Saturday, May 11, 8:30 am - 12:30 pm

Poster Session, Vista Ballroom

23.501 **Processing of collision information in the human superior colliculus** Peng Zhang[1](zhang870@umn.edu), Sheng He[1,2]; [1]State Key Lab of Cognitive Sciences, Institute of Biophysics, Chinese Academy of Sciences, [2]Department of Psychology, University of Minnesota

Detecting looming objects with imminent collision is crucial for survival. The involvement of the human subcortical visual pathway in processing such threatening information remains unclear. Using fMRI, we investigated the functional properties of the superior colliculus (SC) in responding to potential collision information, with or without attention to or consciousness of the colliding object. In experiment 1, subjects judged whether a looming object was on a collision course with the subjects' head. BOLD response of the SC was stronger when the looming stimulus was on vs. off a colliding course. SC response to collision was also lateralized - stronger when the collision stimulus originated from the contralateral rather than ipsilateral visual field of the SC; and stronger when the would-be point of collision was contralateral than ipsilateral to the SC. In experiment 2, subjects' attention was directed to a demanding central fixation task, and consequently no reliable BOLD responses were found in the SC to the looming event, suggesting that some level of attention is needed for the SC to process the collision information. In experiment 3, awareness to the collision object was greatly reduced by presenting the looming stimulus briefly (233 ms) and together with nine other near miss distractors. Results showed stronger SC activities to looming targets on than off the collision course, even when subjects were unable to correctly detect the collision event. These results suggest that SC plays a critical and spatially specific role in the processing of collision information, and this neural process in SC is dependent on the availability of attention but not explicit awareness of the threatening information.

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23.502 **Impaired response-conflict resolution in ageing when high salient distracters compete for response** Lilach Shalev[1,2](lilachsm@tauex.tau.ac.il), Carmel Mevorach[3]; [1]The Constantiner School of Education, Tel-Aviv Universtiy, Israel, [2]The Sagol School of Neuroscience, Tel-Aviv University, Israel , [3]School of Psychology, University of Birmingham, U.K

Top-down attention selection can involve both excitatory processes (biasing attention towards targets) and inhibitory ones (biasing attention away from distracters). In fact, it seems that normal ageing has a differential effect on these two types of processes: While excitatory guidance may be stronger (Madden et al., 1999), inhibitory processes may be selectively weaker in ageing (Lustig et al., 2007). Though the degraded inhibition might be compensated by increased excitatory guidance, performance could be impaired in those scenarios where high-salience distracters compete for selection. In the present study we compared performance of young and old adults in a salience-based selection task which enabled us to separate competition for response from competition for perceptual representation. Superimposed faces and scenes where used in which either the face or the scene was more salient than the other. In Experiment 1 participants identified the face (ignoring the scene) or the scene (ignoring the face) while in Experiment 2 only the face had to be identified (and therefore the scenes did not elicit competing responses). Old adults showed an extraordinary impairment in identifying faces/scenes when the scenes/faces had high-salience but this only happened in the response competition condition (Experiment 1). When response competition was eliminated old adults' performance was comparable to young adults. The results support previous studies that have demonstrated impaired inhibition of incongruent distracters in ageing (Zhou et al., 2011) while further emphasizing that normal aging entails impaired ability to resolve conflicting responses rather than conflicting stimuli. Moreover, the results mimic our previous findings with left parietal patients (Mevorach et al., VSS 2012; using a similar design) and may therefore raise the hypothesis that degraded left parieto-occipital circuitry is the cause for reduced inhibitory top-down attention in old age.

23.503 **Attentional base response in intermediate layers of human superior colliculus measured using high-resolution fMRI** Sucharit Katyal[1, 3](sucharit@mail.utexas.edu), David Ress[1, 2, 3]; [1]Psychology, University of Texas at Austin, [2]Neurbiology, University of Texas at Austin, [3]Imaging Research Center, University of Texas at Austin

Purpose: Human SC has a retinotopic response when covert attention is deployed upon a visual stimulus. Here we tested if SC also exhibits a "base response," an attentional response in the absence of high-contrast visual stimulation, which has been observed in visual cortex during threshold contrast detection. Methods: Subjects (N = 3) fixated and, cued by a small arrow, alternated their attention between two black-outlined sectors located to the left and right of fixation, in 12-second blocks, attempting to detect briefly presented threshold-contrast Gabors. In separate localizer sessions, high-contrast stimuli were used within the same sectors to delineate retinotopic ROIs. Control experiments (N = 2) were performed to test if Gabors of the same contrast and duration evoked a measurable response within SC while subjects performed a demanding fixation-point task. For all experiments, high-resolution fMRI (1.2 mm voxels, 3-shot spiral) was acquired (3 sec/volume) in 8 slices covering SC (24-sec period, 9 cycles/run). Results: There was a significant base response in all six individual ($p < 0.01$) and combined colliculi ($p \sim 0$) within localized ROIs. Responses between left and right colliculi were counter-phase, as expected. In the control experiment there was no significant stimulus-evoked response in all four individual ($p > 0.15$) and combined colliculi ($p > 0.68$). Laminar depth-profiles showed that the peak of the base response occurred significantly ($p < 0.005$) deeper (~1.4 mm) than the superficial response of attention toward high-contrast stimulation (~0.4 mm) observed in our previous study (Katyal et al, J Neurophysiol 104:3074, 2010). Conclusion: Our results are consistent with the laminar dissociation of responses by neuronal subtypes within SC observed in monkeys. Intermediate layer visuomotor neurons receive projections from FEF and exhibit non-stimulus-evoked attentional enhancement. Our results here demonstrate a similar top-down attentional effect during threshold contrast detection in the intermediate layers of human SC using fMRI.

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23.504 **Evidence for Attentional Sampling in the MEG Gamma Band Response** Ayelet Landau[1](ayelet.landau@gmail.com), Helene Schreyer[1], Stan Van Pelt[1], Pascal Fries[1]; [1]Ernst Strüngmann Institute (ESI) for Neuroscience in Cooperation with Max Planck Society

Overt exploration or sampling behaviors, such as whisking, sniffing, and saccadic eye movements are often characterized by a theta/alpha rhythm (4-10Hz; Otero-Millan, Troncoso, Macknik, Serrano-Pedraza and Martinex-Conde, 2008; Buzsaki, 2006). In addition, the electrophysiologically recorded theta or alpha phase predicts global detection performance (Busch, Dubois and VanRullen, 2009; Methewson, Gratton, Fabioani, Beck and Ro, 2009). These two observations raise the intriguing possibility that covert selective attention samples from multiple stimuli rhythmically. To investigate this possibility, we measured change detection performance on two simultaneously presented stimuli. Previously we have found that following a reset event to one location, detection performance fluctuated rhythmically. Additionally, different locations were associated with different (opposing) phases of the rhythmic sampling supporting a sequential model of sampling. This suggests that selective attention entails exploration rhythms similar to other exploration behaviors. Spatial attention has been mechanistically linked to gamma band activity in visual brain regions. Gamma band synchronization is a proposed mechanism supporting inter-areal communication of behaviorally relevant stimuli (Bosman et al., 2012). In the present study, we used MEG to identify bilateral sources of gamma-band activity induced by two corresponding contralateral stimuli. In contrast to the behavioral evidence, the assessment of stimulus-specific gamma responses allowed the investigation of fluctuations preceding lateralized target events without requiring a flash event. We find that band-limited power in the gamma band fluctuates at a theta/alpha rhythm, and the phase of gamma-band power fluctuations predicts behavioral outcome. Importantly, different behavioral outcomes (hits vs. misses) are preceded by opposing phases of the theta/alpha fluctuations. These findings provide further support for the idea that attention to multiple locations is supported by sequential sampling and suggest a functional role for cross frequency coupling between sustained gamma band response and lower frequencies in the theta/alpha range.

23.505 **Selective attention modulates the nonlinear interaction between stimuli**

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Prior studies suggest that visual attention selects objects of interest by biasing the competition in favor of attended items. However, neurophysiological studies of selective attention to one of two objects typically report aggregate responses to individual objects as well as to their interaction. To separate these two response components, we directly measured the interaction between stimuli by using high-density steady-state visual evoked potential (SSVEP) combined with cortical source localization. This technique offers a powerful approach to directly measure attentional modulation of individual stimuli (self-terms) as well as their nonlinear interaction (intermodulation terms). Observers were tested with a pair of adjacent wedge-shaped gratings flickering at two different frequencies (F1 and F2 at 7.14 and 5.56 Hz, respectively). By asking observers to attend to both stimuli or to one of them in separate conditions, we determined the attentional modulations of self-terms and intermodulation terms compared to a condition when observers attended away from the flickering gratings to two static wedges located diametrically opposite the flickering wedges. Our data show that selective attention differentially modulates self-terms at harmonics of F1 and F2 as well as intermodulation terms at the frequency F1+F2. Consistent with previous single-cell studies, the self-terms have the greatest amplitude when attention is directed to one of the two stimuli. In contrast, the intermodulation term has the greatest amplitude when observers attend to both stimuli, is smaller when they attend to a single stimulus, and insignificant when attention is directed away. A similar pattern is seen in cortical source-imaged activities in various ROIs, indicating that the intermodulation term serves as an index of attentional selection throughout the cortical hierarchy. Current study advances our understanding of processes involved in selective attention by separately tracking response components resulting from individual stimuli and from their nonlinear interaction.

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23.506 **Coding of changes in motion direction by local field potentials in primate area MT**

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In primate area MT, direction-selective neurons convey information about a stimulus' motion direction, as early as in their initial response. These neurons may also selectively signal transient changes in motion direction by increasing or decreasing their firing rate depending on whether the direction change deviated closer to or further away from their preferred direction. These properties may thus serve to detect and discriminate changes in a stimulus' feature. Another potential source of neuronal encoding of motion direction relies on the activity of local field potentials (LFPs). Indeed, LFPs in area MT are tuned for motion direction, in a frequency-dependent manner. It is, however, unclear whether LFPs can provide a reliable signal to detect and discriminate changes in a stimulus' feature. To investigate this issue, we recorded LFPs and spiking activity of direction-selective neurons in area MT of monkeys trained to covertly detect a 30-degree motion direction change in one of two moving RDPs. On each trial, both RDPs moved either in the preferred or antipreferred (AP) direction, and thus the actual motion direction after the change deviated away from either the preferred or the AP direction. Across the neuronal population (n=73), the motion direction change evoked a significant ($p<0.05$) decrease or increase in firing rates when the change deviated the motion direction away from preferred and AP, respectively. The direction change also induced changes in the LFP power in all frequency bands. However, only the gamma-band power reflected the identity of the change, being significantly larger when the change deviated the motion direction away from AP compared to away from preferred. These results indicate that the detection of transient stimulus changes can be encoded by LFPs in all frequency bands, while the discrimination of the type of change may be encoded by LFPs in the gamma band.

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23.507 **Optogenetic stimulation of the frontal eye field in an awake, behaving monkey.**

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Optogenetics is a new tool in neuroscience that allows researchers to control neuronal activity with stimulation of exogenously expressed light-sensitive transmembrane ion channels. Since the introduction of this technique in 2005, it has been increasingly relied upon for its high spatial and temporal resolution; that is, the ability to depolarize or hyperpolarize spatially localized neurons of a defined genetic population with millisecond-scale induction and reversibility. Despite the methodological advantages of optogenetics, few groups have successfully implemented it in the study of visual processing in primates. Our laboratory applied optogenetics to the study of visual processing in the prefrontal cortex. We injected the excitatory opsin channelrhodopsin-2 (ChR2) into the frontal eye field of a cynomolgus monkey (Macaca fascicularis). ChR2 was carried with a lentivirus vector and expressed under control of the Thy 1 promoter (Lenti-Thy 1-ChR2(H134R)-eYFP). Injection sites were visually identified using anatomical landmarks in the right hemisphere, ventral to the dorsomedial aspect of the arcuate sulcus. Approximately 6 months after injection, we measured single unit activity in this region in the awake, behaving monkey using a single electrode coupled to an optic fiber and a monochromatic blue laser (473 nm). Measurements of neuronal activity during baseline and optical stimulation were carried out while the monkey fixated on a 1° fixation point on a projection screen. Light-induced neuronal activity was observed in multiple neurons over several weeks. These neurons exhibited up to 70-fold increases in firing rate during the optical stimulation compared to baseline activity. Preliminary immunohistological analyses of transfection efficiency of this viral construct in a separate brain region show transfection of both astrocytes and neurons; further analyses of the proportion and genetic identity of transfected cells are ongoing.

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23.508 **ERP indices of reflexive attention effects on visual search**

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How does involuntary attentional capture affect visual processing and reorienting during search? Reflexive attention facilitates responses and enhances visual processing during target discrimination in simple cueing studies. Although voluntary cues also cause behavioral and neural enhancement of target processing, Kiss et al. (2009) found no effect on target selection during search following voluntary attentional shifts, nor any differences in the event-related potential (ERP) thought to index selection during search, the N2pc. Another ERP component, the invalid ipsilateral negativity (IIN; Hopfinger & Mangun, 2001), has been proposed as an index of disengagement and reorienting following involuntary attentional capture. The present ERP study aimed to dissociate mechanisms of spatial reorienting from distractor suppression, and determine how reflexive attention affects discrimination during pop-out search. A non-predictive peripheral cue was rapidly followed by a pop-out search to compare differences in target processing when attention was either captured to the target's location in advance (cued targets), or had to be reoriented from an erroneous loca-

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tion to the target (uncued and neutral targets). ERP indices of early visual processing (e.g. P1 component) showed a significant enhancement for cued relative to uncued-location targets and neutral targets. Cued-location targets produced the largest N2pc, suggesting that the amplitude of this component is related to the amount of attentional resources employed during selection rather than the act of shifting the focus of spatial attention. A significant IIN was found at a longer latency than in previous cueing paradigms, occurring after the N2pc, and in the condition in which the N2pc was smallest. These results indicate that: (1) reflexive attention enhances early sensory processing during visual search, (2) the N2pc is an effective marker of the location of attention, not an index of shifting spatial attention, and (3) the IIN is a potential index of reorienting following involuntary capture.

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23.509 The neural mechanism of attention shifting triggered by eye gaze

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Attention is considered a central component of cognitive functioning. While many studies have demonstrated that eye direction can trigger reflexive attention shifting. To explore this issue we present results from an voluntary attention shifting task. The results show significant reflexive attention shifting. The event-related potential (ERP) experiment using the spatial cueing task, in which females show larger cueing effect and larger ERP component amplitude. Detailed research questions are as follows: The first experiment mainly examined whether visual attention shifting could be trigger by eye gaze, and the neural mechanism and time course of reflexive attention shifting. The result showed that there was voluntary and reflexive attention shifting triggered by eye gaze and the attention shifting showed brain asymmetry. The process of attention shifting triggered by eye gaze includes the processes of eye gaze processing and attention shifting. To further understand attention shifting triggered by eye gaze, we examined the processing of eye gaze in the second experiment. The results showed that men had an advantage of processing eye gaze. In the early period, the left hemisphere has an advantage, and later the right hemisphere began to play a major role. The findings in this study: 1. Reflexive attention shifting triggered by gaze cannot be controlled or inhibited. 2. In the early period (100□200ms) of attention shifting triggered by eye gaze, the left hemisphere has an advantage, and later (210□370ms) the right hemisphere begins to play a major role. 3. In the early period (before 190ms) of the processing of eye gaze, the left hemisphere has an advantage, and later the right hemisphere begins to play a major role.

23.510 Functional Chronometry of V5 and Middle and Posterior Intraparietal Sulcus in Motion-Driven Attention- A Neuronavigated TMS Study

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Visuospatial motion processing is a critical behavioural function known to involve networks of rapidly activated areas including motion area V5, and spatial attention related areas in parietal cortex. The current experiment sought to investigate the functional chronometry of area V5, mIPS, and pIPS, based on individual fMRI in the performance of the Motion-Driven Attention task. It was hypothesized that TMS of these regions would lead to decreased performance early after motion onset, and then again at approximately 150 ms. Nine participants performed the task during paired-pulse TMS with seven stimulus onset asynchronies between 0 and 180 ms. The task required identification of a stimulus defined by coherent motion moving across one visual quadrant. TMS of V5 did not lead to statistically significant effects, though individual data indicates early activation in most participants. TMS of mIPS led to a relative decrease in performance on the Motion-Driven Attention task at 150 ms, and a trend towards an early decrease at 30 and 60 ms. TMS of pIPS showed a significant decrease in performance at 0 ms which could be interpreted as an interruption of vigilance. The timing found for mIPS is consistent with our previous reports of early and later V5 activation possibly suggesting feedforward/feedback coupling of these areas during processing of motion driven attention.

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23.511 Population Attentional Field Modeling

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The stimulus evoked fMRI signal of single voxels in human visual cortex can be accurately predicted using a population receptive field (pRF) model (Dumoulin, 2008). We have adapted this approach to explore the effects of visual attention on single voxels. While fixating at a center marker, subjects (4) were cued to covertly attend to a specific target location within a dartboard-like array of stimulus segments that slowly rotated about fixation at 0.75 rpm. In attention runs, subjects continuously tracked a single target at 8o eccentricity within the array. In sensory runs, the previously attended segment was presented in isolation while subjects performed an attention task at fixation. In the attention condition, voxels having pRFs positioned along the trajectory of the target segment were differentially activated when the focus of attention passed over their pRF. These voxels were also activated in the sensory condition when the isolated stimulus segment passed over the pRF. Thus, the duration of fMRI activation was proportional to either (1) the width of the attentional focus or (2) the width of the stimulus segment, thereby allowing a direct comparison of the relative sizes of the two. To compute the relative widths precisely for each voxel, we fit the empirical data with a timecourse generated by a model composed of the stimulus sequence, the attentional field, the voxel's estimated pRF, and the temporal hemodynamic response function. The resulting model parameters were compared to estimate the relative sizes of the attentional field and the sensory stimulus. Recent models of visual attention indicate that the size of the attentional field relative to a visual stimulus and sensory pRF are key factors in determining the behavioral effects of attention (Reynolds, 2009). The method described here permits empirical measurement of the attentional field size thereby providing key information for models of attention.

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23.512 Neural representation of the bottom-up saliency map of natural scenes in human primary visual cortex

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Zhang and colleagues recently showed that neural activities in V1 could create a bottom-up saliency map (Neuron, 73, 183-192, 2012). In that study, they used simple bar textures and a salient region was created by the orientation contrast between foreground and background bars. Here, we tested if their conclusion can generalize to complex natural scenes. Fifty natural images were selected from the internet based on the output of a prominent saliency model proposed by Itti and Koch (1998). The model predicted that all the natural images had a focal, lateral salient region, which was confirmed by a psychophysical experiment. In the experiment, to avoid top-down influences, each image was presented with a low contrast for only 50 ms and was followed by a high-contrast mask, which rendered the whole image invisible to subjects (confirmed by a forced-choice test). The Posner cueing paradigm was adopted to measure the spatial cueing effect (i.e. saliency) of the predicted salient region on an orientation discrimination task. A positive cueing effect was found and the magnitude of the cueing effect was consistent with the saliency prediction of the model. In a following fMRI experiment, we also used the masked natural scenes and measured BOLD signals responding to the predicted salient region (relative to the background). We found that the BOLD signal in V1, but not in other cortical areas, could well predict the cueing effect. These findings suggest that the bottom-up saliency map of natural scenes could be constructed in V1, providing further compelling evidence for the V1 saliency theory (Li, 2001).

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23.513 The Attentional Attraction Field: A feed-forward model of attention

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Visual attention is considered to be a selection process that favors some aspects of the visual input over others. A multitude of attentional effects were found for both neural and behavioral responses, however, the nature of the attentional mechanism is an unsettled issue. Models of attention typically attempt to explain attentional effects by some top-down mechanism. There are indeed findings showing that higher visual areas in the visual hierarchy are affected by attentional modulations prior to lower ones, however, these modulations were observed while participants (whether primates or human) practiced sustained (volitional, endogenous) attention. Yet, attention may also be attracted involuntarily by events or stimuli in the visual field (i.e., reflexive, exogenous attention). Here we propose a feed-forward model that is based on the conception of attention as an attraction field: The allocation of attention to a location attracts (shifts) the centers of receptive fields towards this location. We show that the influence of this attraction mechanism propagates up the visual hierarchy, and can serve as a simple unifying framework to explain a diverse range of spatial as well as temporal attentional effects, including gain enhancement, enhanced contrast sensitivity, enhanced spatial resolution, prolonged temporal integration, prolonged perceived duration, prior onset and degraded temporal resolution. Additionally, the model successfully explains the Mexican-hat profile of attention and distortions at the focus of attention. Thus, this model offers a simple mechanism that can explain reflexive attention linking physiological measurements at the unit level with psychophysical observations of both the spatial and temporal domains of perception.

23.514 **Subitizing and estimation emerge from a computational saliency map model of object individuation** Rakesh Sengupta[1](qg.rakesh@gmail.com), S. Bapiraju[1], David P. Melcher[2]; [1]Center for Neural and Cognitive Sciences, University of Hyderabad, [2]Center for Mind/Brain Sciences (CiMec), University of Trento

One of the principal tasks of vision is to extract information about individual objects and groups of objects from the retinal image. This has led to the suggestion that our core sense of number emerges from these basic perceptual processes (Feigenson et al., 2004, TRENDS in Cognitive Sciences, 8, 307-314). We extended a recent model of saliency maps in human parietal cortex (Roggerman et al, 2010, NeuroImage, 52, 1005-1014) to account for human numerosity judgements within both the subitizing and estimation ranges using a single parameter: the inhibition between connected neural nodes in the lateral intraparietal (LIP) region that encode spatial locations. This inhibition parameter is known to be task dependent and can be quantified through fMRI beta regression values (Roggerman et al, 2010). Building on this work, we incorporated this inhibition parameter into a model of neural activation during enumeration which predicted a cost in reaction times when switching from the estimation of large numerosities to the subitization of small numerosities, as well as systematic underestimation when switching from subitizing to estimation. To test our model we designed an enumeration experiment with subitizing and estimation blocks of variable lengths and measured voice-onset reaction times and the enumeration accuracy. Our findings confirmed the predictions suggesting a shared mechanism for subitizing and estimation.The model provides an explanation for the human number sense which cannot be reduced to low-level visual properties like density of texture or spatial frequency (Burr et al, 2008, Current Biology, 18, 857-858) but instead emerges from high-level neural mechanisms which individuate visual-spatial entities.

23.515 **Oscillatory coupling reveals the dynamic reorganization of networks processing reward, maintaining working memory and controlling attention** Robert M.G. Reinhart[1](robert.reinhart@vanderbilt.edu), Geoffrey F. Woodman[1]; [1]Psychology Department, Vanderbilt University

It is unclear how the brain dynamically forms and reforms different large-scale networks underlying specific cognitive operations across different phases of a given task. Here we show that when subjects were given the opportunity to earn a large reward, theta and beta oscillations over prefrontal regions formed a distributed network defined by the coupling of these distinct frequencies. Next, we found that as subjects maintained a representation of a target object in visual working memory, theta and alpha oscillations across frontoparietal areas formed a network distinct from that related to processing reward. Then, as the subjects searched for a target object in complex visual scenes, theta and alpha oscillations across frontotemporal areas formed a third spatially distinct network related to the deployment of visual attention and perceptual analysis of the search array. We found that our measures of network synchronization strength were robust trial-by-trial predictors of upcoming network formation and behavioral response speed and success. These findings are consistent with the hypothesis that oscillatory synchrony is the mechanism for providing fast dynamic regulation of active brain networks, and suggest a functional role for inter-regional cross-frequency interactions in the human brain.

23.516 **Distracter filtering across the visual thalamocortical network** Ryan Ly[1,2](rly@princeton.edu), Yuri Saalmann[1,2], Sabine Kastner[1,2]; [1]Princeton Neuroscience Institute, Princeton University, [2]Department of Psychology, Princeton University

One function of visual attention is to filter out distracting objects. Currently, there is evidence for operations of distracter filtering in areas of the ventral visual stream such as V4 (de Weerd et al., 1999, Nat Neurosci). However, little is known about distracter filtering and its neural mechanisms in other parts of the visual system. We explored distracter filtering in V4, the lateral intraparietal area (LIP) of the dorsal visual stream, and the pulvinar nucleus of the visual thalamus, which has been implicated in distracter filtering from lesion studies (Snow et al., 2009, PNAS; Desimone et al., 1990, CSH Symp Quant Biol). We simultaneously recorded single-neuron activity from these areas of two macaque monkeys performing a variant of the Eriksen flanker task (Eriksen, 1995, Vis Cogn). Macaques were trained to detect a target shape (barrel /bowtie) that was flanked by either congruent distracters (same shape as the target) or incongruent distracters (dissimilar shape to the target). Similar to human behavioral performance, reaction times were faster on congruent versus incongruent trials. We calculated spike density functions for all cells and compared their responses to the target when flanked by congruent versus incongruent distracters. Neurons in V4, LIP, and the pulvinar showed shape selectivity, with more cells showing preference for convex over concave shapes, as previously shown in V4 (Pasupathy and Connor, 1999, J Neurophysiol). When the monkeys correctly identified the target amid distracters, cells were sensitive to the incongruence of nearby distracting stimuli. This sensitivity was seen in both dorsal and ventral visual streams, as well as in the thalamus. These preliminary results suggest that an extensive visual thalamocortical network contributes to distracter filtering, beyond what has been previously shown in the ventral visual stream. The involvement of the pulvinar further supports its important role in visual attention.

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23.517 **Cognitive Programs: Towards an Executive for Visual Attention** John Tsotsos[1,2](tsotsos@cse.yorku.ca); [1]Dept. of Computer Science and Engineering, York University, [2]Centre for Vision Research, York University

We address the question of what are the computational tasks that an executive controller for visual attention must solve. This question is posed in the context of the Selective Tuning model of attention (Tsotsos 2011); however other attention models are considered as well (for example, see Baluch and Itti 2011). The range of required computations go beyond the expected top-down attention signals or region-of-interest determinations, and must deal with parameter settings, timing and synchronization of processes, information routing, a range of recurrent mechanisms, coordination of bottom-up with top-down information, matching control to task, and more. Within Selective Tuning, the attentive mechanisms of suppression, restriction and selection are defined and several sub-classes of each. There are also 'beyond feed-forward' processes including recurrent localization, early dorsal-to-ventral recurrence, priming, and cueing. Overt and covert fixations are both supported. All of this must be coordinated, communications synchronized, and the results monitored to ensure the expected results are obtained, as the given task requires. We show how these play a role in the overall shaping of attentional modulation of the visual system so that it provides its best performance: the system is a dynamic one, tuning a general purpose processor to the task and input of the moment. The framework of computation that might suffice for an attention executive will be described. Importantly, one must also consider the communications to and from the attention executive. To accomplish this, the classic, seminal contribution of Ullman's Visual Routines is resurrected, re-defined to make it consistent with the modern neurobiology of vision, re-named Cognitive Programs, and developed to include the critical elements of Visual Task Executive, Attention Executive, and Working Memory.

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23.518 **Overt Fixations Reflect a Natural Central Bias** Calden Wloka[1,2](calden@cse.yorku.ca), John Tsotsos[1,2]; [1]Computer Science and Engineering, York University, [2]Centre for Vision Research, York University

A common characteristic of psychophysical eye-tracking data taken during free-viewing conditions is a strong central bias in the set of fixation locations. Although trends in photographic composition may contribute to a centralized distribution of fixations, a more fundamental explanation arises from a train of explicit overt fixations. We show first that a 2D random walk of fixations implicitly encodes a central bias. Based on that result, we implement a saccade controller for overt fixational control. The saccade controller

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consists of three distinct modules: a peripheral priority map (PPM), a fixational history map (FHM), and an history-biased priority map (HBPM). In the absence of top-down tuning, the PPM functions in the same manner as a saliency map, while the FHM provides inhibition of return functionality. The HBPM combines input from the central candidate for attention, the PPM, and the FHM to determine the next fixation target. Using the saccade controller in conjunction with the AIM saliency algorithm (which does not contain a central bias component) we demonstrate an improved performance in reproducing more human-like fixation patterns.

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23.519 **A Bayesian model for visual salience learning** Jinxia Zhang[1,2](jxzhang.china@gmail.com), Jundi Ding[1], Jingyu Yang[1]; [1]Nanjing University of Science and Technology, [2]Brigham and Women's Hospital

We present a Bayesian model for visual salience learning in natural scenes. The model evaluates each point in the scene as belonging to the salient or non-salient class. The computed salience value of the point corresponds to the probability that it belongs to the salient class. From Bayesian probability theory, we derive three components of visual salience. For the situation in which observers are viewing the scene with no explicit goal, these salience modules are Rarity, Distinctiveness and a Central bias. The Rarity module computes a global property, comparing a point to all points in the scene. The Distinctiveness module uses local contrast to compare each point to all other points, but biased toward the local neighborhood. Finally, a Central bias serves as the location prior when no other task is given. A neural network, using a back-propagation algorithm, learns a weighted, nonlinear combination of these modules to generate the final saliency map. We use this model to predict human eye fixations and to segment images. The saliency map used to predict eye fixations is created from multi-scale representations of features and is computed on a pixel by pixel basis. The experimental results on two fixation databases indicate that our method outperforms other representative methods. For image segmentation, the goal is to uniformly highlight the most salient, foreground object and darken the background. In this case, an image is first over-segmented into a number of regions using the mean-shift method. Then salience is computed using single-scale features on a region by region basis. This generates a high-resolution saliency map which uniformly highlights the salient object and well defines the borders of the object. The experimental results on the salience segmentation database indicate that our method shows better figure-ground segmentation than other representative methods.

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23.520 **A normalization model of attention predicts enhanced contrast appearance** Elizabeth Cutrone[1](ekc281@nyu.edu), David J. Heeger[1,2], Marisa Carrasco[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Goal. Attention to a stimulus increases neural responses and increases perceived contrast. Here we investigated how perceived contrast is linked to changes in neural activity by fitting psychophysical measurements of contrast appearance with a computational model of visual cortical responses. Method. Observers viewed two tilted Gabor stimuli (test and standard) on each trial and reported the orientation of the stimulus that appeared to have higher contrast (2-AFC). Exogenous attention was manipulated via a pre-cue, either at fixation (neutral) or near the location of either stimulus. We measured the point of subjective equality (PSE), the contrast at which observers chose the test stimulus with probability 0.5, for six standards of different contrasts. We used the normalization model of attention (Reynolds and Heeger, 2009) to predict neural responses corresponding to the different pre-cues (neutral, cue-test, cue-standard), then fit the model to the psychophysical PSEs. Results. Attention significantly boosted perceived contrast: the PSE was higher when the standard was cued compared to the neutral cue, and lower when the test stimulus was cued. In the best-fitting model, the pre-cue caused an increase in the baseline activity of simulated neurons with corresponding receptive fields. Conclusions. The effect of attention on perceived contrast is mediated by an additive increase in neural responses. This baseline increase is qualitatively consistent with fMRI measurements of visual cortical responses to attended stimuli. Reynolds JH & Heeger DJ, Neuron, 61:168-185, 2009.

Acknowledgement: NIH R01-EY019693 (to DH and MC)

Perceptual learning: Models, specificity

Saturday, May 11, 8:30 am - 12:30 pm

Poster Session, Vista Ballroom

23.521 **Learning of eye movements for human and optimal models during search in complex statistical environments** Emre Akbas[1](emre.akbas@psych.ucsb.edu), Kathryn Koehler[1], Miguel P Eckstein[1]; [1]Department of Psychological & Brain Sciences, University of California, Santa Barbara, Santa Barbara

Little is known about how organisms modify their eye movements to optimize perceptual performance. Here, we investigate changes in human eye movements given practice at a visual search task with a complex statistical structure and compare these to a foveated Bayesian ideal learner (FBIL) that uses posterior probabilities from previous trials as priors in subsequent trials to plan saccades. Methods: Seven participants searched for a vertically aligned Gabor (8 cycles/deg) signal (yes/no task with 50% probability of target presence) embedded in spatiotemporal whitenoise. The image was briefly presented (500ms) and subtended 22.2x29.6° visual angle. If present, the signal always appeared in the one of six locations (with equal probability per location) arranged around a circle with a radius of 4.4° whose center was located 16.6° from initial fixation. Participants were informed that there were six possible equi-probability target locations, but were given no information about their spatial configuration. A separate study measured each observer's detectability of the target as a function of eccentricity (visibility map). Results: All but one participant's perceptual performance improved across the 3600 trials (mean Δ proportion correct between first and last 100 trials: 0.19 ± 0.03). For these six observers, the mean distance of their saccade endpoints to the nearest possible target locations diminished from $6.22\pm0.63°$ in the first session to $1.68\pm0.05°$ in the last session. Based on the human visibility maps, the FBIL predicted that human eye movements should converge to the center of the six possible locations. Instead, observers' learned eye movements converged close to one of the six possible locations, a result that was better predicted by a learning saccadic target model (maximum a posteriori probability, MAP). Conclusion: Humans can learn to strategize eye movements to optimize perceptual performance but that for environments with complex statistical structure they fail to fully learn optimal gaze strategies.

Acknowledgement: This work was supported by Grant EY-015925 from the National Institutes of Health to M.P.E.

23.522 **Statistical learning, a singular process? Dissociating behavioral outcomes of visuo-temporal statistical learning** Brett C. Bays[1](bbays001@ucr.edu), Nicholas B. Turk-Browne[2], Aaron R. Seitz[1]; [1]Department of Psychology, University of California, Riverside, [2]Department of Psychology, Princeton University

Statistical learning (SL) refers to the implicit learning of patterns among stimuli organized according to probabilistic relationships. In the visuo-temporal domain, a common paradigm involves exposure to a stream of unique shapes that, unbeknownst to the subject, has been generated from shape pairs or triplets. A variety of tasks have been employed to identify behavioral effects of SL and these are often considered to be interchangeable measures of learning. Here we operationalized SL using multiple measures of learning and found that SL may be composed of dissociable processes. In Experiment 1, subjects were exposed to a steady stream of stimuli as they performed an online task of periodically indicating whether a stimulus was present or absent, while the overall contrast was staircased to the subjects' threshold levels. Decreased response latency to the third vs. first item in triplets demonstrated learning, albeit with large variance. Experiment 2 replicated Experiment 1 and added an RSVP target detection post-task. There was a clear SL effect in target detection speed, which we used to categorize which triplets had been learned for further analysis of performance during the exposure task. Examining 'learned' vs. 'unlearned' triplets separately revealed a counter-intuitive finding: only unlearned triplets showed speeded responses in the present/absent task as a function of triplet position. These results were replicated in further experiments where we used a recognition memory post-task in place of the RSVP post-task (Experiment 3) and where we added foils to measure baseline performance (Experiment 4). Taken together, these results show that the SL process supporting speeded responses in the exposure task was different from the SL process that was expressed in the RSVP and memory post-exposure tasks. Thus, SL may consist of a family of processes that can produce dissociable effects on different aspects of behavior.

Acknowledgement: NSF (BCS-1057625) and NSF IGERT: Video Bioinformatics Grant DGE 0903667

See page 3 for Abstract Numbering System

23.523 An Optimal Read-Out Model of Perceptual Learning: How to Measure Task Difficulty and Learning Specificity in a Principled Manner

Alexander A Petrov[1](apetrov@alexpetrov.com); [1]Department of Psychology, Ohio State University

Task difficulty is an important determinant of the amount, speed, and specificity of perceptual learning (Ahissar & Hochstein, 1997). Yet the field lacks a principled definition of "difficulty" and resorts to ceteris paribus shortcuts instead. For example, all else being equal, high-noise conditions are more difficult than low-noise conditions, high-precision discrimination is more difficult than low-precision discrimination, etc. The problem is that such ceteris paribus assumptions are violated in learning experiments because the performance improves with practice and because of the methodological necessity to manipulate at least two independent variables -- one to define difficulty levels between subjects and another to track thresholds within subjects. Which condition is more difficult: low-precision discrimination in high noise or high-precision discrimination in low noise? A principled answer to such questions must measure the information content of a given stimulus with respect to a given discrimination task. We propose an Optimal Read-Out (ORO) Model based on the Theory of Ideal Observers (TIO, Green & Swets, 1974). The main innovation is that, whereas TIO works with the conditional probability densities of the stimuli themselves, ORO works with the densities of their V1 representations under standard assumptions about the response properties of V1 neurons (Petrov, Dosher, & Lu, 2005). The optimal discrimination boundary is defined as the locus of points in representation space where the likelihood ratio equals one. The optimal d' is calculated by integrating the "hit" and "false alarm" densities on either side of the boundary. In our implementation this involves Monte Carlo integration in 200 dimensions. The efficiency of a human observer -- the squared ratio of their behavioral d' to the optimal d' -- improves with practice and can be compared across conditions. Whereas the absolute efficiency is parameter-dependent, the relative efficiency is not, and it is the latter that is theoretically relevant.

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23.524 Apparent similarity in context: Similarity increases with frequent large differences between stimuli

Alexander N. Sokolov[1](alexander.sokolov@uni-ulm.de), Joachim F. Eicher[1,2], Paul Enck[1]; [1]Research Division, Department of Psychosomatic Medicine and Psychotherapy, University of Tübingen, D 72076 Tübingen, Germany, [2]Neurobiology and Biophysics, Institute of Biology III & Bernstein Center for Computational Neuroscience, University of Freiburg, D 79104 Freiburg, Germany

In daily life, we used to rely upon apparent similarity when missing specific knowledge about things or recalling people and places. In cognitive neuroscience, measures of apparent similarity are taken to build spaces of sensory representations. However, if similarity is context-dependent is largely unknown. Statistical context (i.e., overall base rates and initial encounters of distinct stimuli) can modulate perceived magnitudes of single stimuli: For instance, the same speed appears lower with fast rather than slow speeds possessing higher overall base rates or dominating the series outset (the frequency and primacy effects; Sokolov et al., 2000). When judging similarity, small differences between stimuli are typically more common than large differences. Here, we examined whether the frequency (i.e., overall base rate) and initial encounters of distinct stimulus pairs affect perceived similarity. Six Gabor patches (spatial frequency, 1-10 cycle deg-1 in 0.2 log-steps) were presented in pairs to four separate groups of healthy adults who had to judge their similarity using a 3-point scale (hardly, moderately, and very similar). In the groups, patch pairs with either large or small differences possessed higher overall base rates and/or dominated the initial trials. The results showed that regardless of which (small or large) differences mainly occurred on the initial trials, similarity judgments greatly increased with on overall more frequent pairs of large rather than small differences, indicating a frequency effect. We conclude that apparent similarity largely depends on the statistical context of stimuli. The outcome suggests important implications for computational models of sensory representations that should take proper account of variable base rates of stimulus pairs.

23.525 The acquisition of hidden models in humans

Devika Narain[1](d.narain@fbw.vu.nl), Pascal Mamassian[2], Eli Brenner[1], Jeroen B.J. Smeets[1], Robert J. van Beers[1]; [1]Faculty of Movement Sciences, VU University, Amsterdam, The Netherlands, [2]Université Paris Descartes V, Paris, France

We investigate how humans discover hidden dependencies among variables in the visual environment over time. We first perform a visuo-motor experiment to establish that it is possible for humans to learn hidden models of varying complexity over time. Participants perform an experiment in which there is a hidden relationship between the value of an observed variable (location of a visual cue) and the required value of the response variable (interception time to a target). This relationship between the location and the time of a target represents models of different complexities (Constant, Linear, Quadratic) that suddenly switch over the course of the experiment. Given the data, we infer which model was being used to generate the responses at different stages of the experiment and simultaneously control for the different number of parameters in each model. We use Bayesian model selection to determine the posterior probability of each model given the data. We find that participants were able to correctly detect whether the hidden relationship in the stimuli followed a constant, linear or quadratic model. When the model that was used to generate the stimuli changed, participants were able to follow the change. In summary, participants constantly monitored the world relationship between the location and the time of a visual event and exhibited a preference for the simplest model that adequately explained the observed data.

23.526 Specificity in learning: Blame the paradigm

Jacqueline Fulvio[1](fulvio@wisc.edu), C Shawn Green[1], Paul Schrater[2,3,4]; [1]Department of Psychology, University of Wisconsin - Madison, [2]Department of Psychology, University of Minnesota, [3]Center for Cognitive Sciences, University of Minnesota, [4]Department of Computer Science, University of Minnesota

Learning studies are often characterized by a lack of generalization to new tasks and stimuli that fundamentally limits the value of training. A long-standing debate is whether the 'curse' of specificity is inherent to learning or may result from a lack of diversity in task and stimuli. By varying the diversity of a set of training stimuli, we show that it is possible to induce two different types of learning: (i) specific learning with limited generalization using a restricted training set; (ii) model-based generalizable learning using a diverse training set. These results suggest that the 'curse' of specificity can be the fault of the paradigm. Observers were asked to launch a 'ball' through three target rings by selecting the correct initial velocity. Observers chose one of 32 launch points on a computer screen that sends a dot along a quadratic 'gravity-influenced' trajectory. Each launch point corresponded to a different initial direction and velocity, visibly revealed by the angle and distance relative to the dot's start point. One group received repetitive training on four ring configurations (4R) and a second receives variable training on 20 (20R); both completed the same number of total trials. Both groups underwent no-feedback pretest, posttest, and interleaved test sessions with new configurations to assess the effect of training experience. While both groups performed similarly at pretest, performance changes at posttest for the two groups showed the predicted consequences of training. 4R observers learned to rely on the four launch points used during training, consistent with a learning strategy that fails to generalize to new stimuli. In contrast, 20R observers expanded their selection range in a manner consistent with an improved understanding of the overall relationship between launch point and trajectory shape.

23.527 Perceptual training boosts separable aspects of visual attention and working memory

Maro Machizawa[1](maro@brown.edu), Dongho Kim[1], Takeo Watanabe[1]; [1]Cognitive Linguistics & Psychological Sciences, Brown University

While how training improves the performance on the trained task itself has been extensively studied, it remains unclear whether and, if so, how such training influences global cognitive functions such as attention and working memory. To address this question, four participants were trained on a texture discrimination task (TDT, Karni & Sagi, 1991,PNAS) on one hemifield for six days (840 trials a day). We assessed behavioral changes in attention and working memory abilities before and after the perceptual training. Specifically we examined effects of training on three attentional components (alerting, orienting, and executive filtering) measured by a Lateralized Attention Network Task (Greene, et al., 2008, Brain Cogn.) and two working memory abilities (precision and capacity) indexed by a visual-orientation working memory task (Machizawa, Goh & Driver, 2012, Psychol. Sci.). As in Karni & Sagi (1991), performance on a TDT improved due to training. With regards to working memory components, performance for the 'precision' of working memory (the ability to retain fewer number of items with fine-precision) showed significant improvement on the trained hemifield ($T3 = 2.75$, $p < .05$, one-tail), but not on the other hemifield ($T3 = 0.21$, $p = .42$, one-tail). The 'capacity' of working memory (the ability to retain a number of items with coarse-precision) significantly increased (estimated number of items can be retained, $K = 3.02$) compared to the pre-training baseline ($K = 2.53$). Notably, such improvement was observed in both hemifields irrespective of which hemifield was trained on TDT. With regards to attentional components, we found a trend of improvement for executive filtering but not for alerting or orienting components. These results demonstrate that training on a visual task not only improves the task performance but also certain aspects of cognitive functions such as attention and working memory. Furthermore, they also indicate precision and capacity of working memory are dissociated.

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23.528 **Modeling perceptual learning of visual motion** Émilien Tlapale[1](etlapale@uci.edu), Barbara Dosher[1], Zhong-Lin Lu[2]; [1]Department of Cognitive Science, University of California, Irvine, CA 92697, [2]Department of Psychology, The Ohio State University, Columbus, OH 43210

Repeated exposure or training on moving stimuli leads to improved performance in tasks such as motion detection or discrimination. Although numerous studies have reported perceptual learning in visual motion, identifying learning mechanisms and their cortical loci remains a major issue. A comprehensive consideration of the existing, and apparently conflicting, literature in a consistent framework is our first step to solve this issue. We incorporate perceptual learning through connectivity reweighting into the dynamical model of Tlapale et al (2010). Since this model, which includes cortical areas dedicated to motion (V1, MT and readouts) and their intra- and inter-area connectivity, has been shown to elicit relevant percepts for a wide variety of motion stimuli, it provides a natural basis to incorporate mechanisms of perceptual learning. The resulting model is then tested on the data of many experiments reported in the literature. We show that a dynamical reweighting model is able to account for various perceptual learning results such as discrimination training (Ball and Sekuler 1982,1987), repeated exposure (Watanabe et al 2001,2002), and the influence of difficulty on learning rate. The existing data can be explained by reweighting the feedforward connectivity of the local motion information (from V1 to MT), confirming the hypothesis of the literature. But reweighting the connectivity on global motion information (from MT to the readout) can also produce results matching the experimental data. To solve this location ambiguity, we propose a motion discrimination task, based on known properties of the visual system in solving the aperture problem. Finally, we generate new predictions of the model for novel stimuli, such as motion transparency detection, or in transfers across different kind of stimuli. As a whole, we present a model of visual motion perceptual learning which describes the existing experiments, and provides new testable predictions to classify mechanisms of motion learning.

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23.529 **Alternating training between tasks enables visual perceptual learning** Sarit Szpiro[1](sarit.sz@gmail.com), Young A Lee[1], Beverly Wright[2], Marisa Carrasco[1,3]; [1]Department of Psychology, New York University, [2]Department of communication sciences and disorders, Northwestern University, [3]Center for Neural Science, New York University

Goal. Perceptual learning is a long lasting improvement in the perception of a stimulus following training. In vision and audition, studies have shown that irrelevant training does not yield learning. However, a recent audition study showed that a given amount of training on one task (frequency discrimination) that is insufficient for learning on its own yields learning when alternated with training on another task (duration discrimination) with a common stimulus (Wright et al. 2010). Here we explored whether a parallel effect is present in vision: Can alternating training between two tasks help learning? Methods. We used orientation (task-A) and spatial frequency (SF, task-B) 2AFC discrimination tasks. On each trial two Gabor patches appeared, a standard and a comparison, and observers compared either their orientation or their SF, depending on the block. During pre- and post-tests, observers were tested on both tasks with a standard Gabor (4cpd oriented 30° or 120°). We trained three groups for three intermediate days with the 30° standard stimulus. Training sessions differed across groups: Group ABAB alternated between the orientation and SF tasks (400 trials/task/day). Groups A–A– and –B–B trained on one task alternating with rest (400 trials/day for each group). Results. We found a significant interaction across groups: Group ABAB had significant learning in both tasks for the trained stimulus, and learning generalized to the untrained orthogonal stimulus in the SF task. In contrast, the other groups (A–A– and –B–B) did not exhibit any learning. Conclusion. As in audition, alternating training between two tasks with the same standard stimulus–even when the same amount of training on each task on its own is ineffective–can facilitate visual learning. These findings suggest a novel visual training paradigm in which task alternation enables learning for both tasks.

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23.530 **Task sets determine implicitly learned stimulus information in spatio-temporal contextual cueing** Yoko Higuchi[1](higuchi@cv.jinkan.kyoto-u.ac.jp), Yoshiyuki Ueda[2], Hirokazu Ogawa[3], Jun Saiki[1]; [1]Graduate School of Human and Environmental Studies, Kyoto University, [2]Kokoro Research Center, Kyoto University, [3]Department of Integrated Psychological Sciences, Kwansei Gakuin University

Attention could be guided to a target object in a search display when either the fixed spatial layouts or the same object sets were presented repeatedly (contextual cueing; Chun & Jiang, 1998; Chun & Jiang, 1999). Previous studies have shown that objects' locations were selectively learned whereas their identities were not, even when both object locations and identities were available for predicting the target location (Endo & Takeda, 2004). However, our previous study found that only objects' identities were selectively learned when objects were sequentially presented at multiple fixed locations (spatio-temporal contextual cueing; Higuchi et al., VSS2012). We investigated whether implicit selective learning of location and identity depends on tasks by devising two different tasks using the identical experimental paradigm: the spatio-temporal contextual cuing. Participants were asked to respond to a target among the stream of distractors presented sequentially at different locations. The target was defined as an object belonging different category (Experiment 1: identity task) and an object with spatial offset (Experiment 2: location task). In the learning phase, invariant sequences both in locations and identities associated with a particular target were presented repeatedly. In the following test phase, either locations or identities of the invariant sequences were randomized. In Experiment 1, reaction times increased in the test phase compared with the last block of the learning phase when the object identities were randomized, whereas reaction times did not change when the locations were randomized. In contrast, in Experiment 2, reaction times increased in the test phase when the object locations were randomized. The participants could not recognize the invariant sequences in both experiments. These results indicate that selective learning of location and identity are task-dependent, suggesting that task sets play an important role in deciding which information was learned implicitly.

23.531 **Effects of Training Difficulty and Noise on Perceptual Learning in Older Individuals** Denton J. DeLoss[1](ddelo001@student.ucr.edu), George J. Andersen[1]; [1]University of California, Riverside

Previous research has shown a wide array of age-related declines in vision. Perceptual learning (PL) may be useful as a possible intervention to combat these declines. PL has been demonstrated to be specific to particular stimulus attributes used during the training, such as orientation and location within the visual field. A number of studies examining PL in older as well as younger individuals have also included external noise in their stimuli. However, no studies to date have examined how training difficulty and the presence of external noise during training affect PL and specificity in older individuals. The current study examined orientation specificity of PL in an orientation discrimination task in older individuals (mean age 71.73, range 65-91). Twenty-two older subjects participated in the study which consisted of seven 2-hour sessions each conducted on separate days. A two-interval forced choice procedure was used with two sequentially presented Gabor patches during which participants indicated whether the second Gabor was rotated clockwise or counterclockwise compared to the first. Thresholds were determined using QUEST for their trained and untrained standards tested on separate days, the testing order and trained standard were counter-balanced across subjects. During days 2 through 6 participants were assigned one of the standard orientations for training in either an easy or difficult training condition which either included external noise (the mid-noise level during testing) or a condition in which no external noise present. Days 1 and 7 used the same procedure to assess orientation discrimination thresholds at five levels of external noise. Results indicate significant learning and that specificity was related to the difficulty of training. In addition, training with external noise increased the degree of transfer to the untrained orientation. No significant differences between subjects prior to training were found.

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23.532 **How lifelong perceptual learning shapes perception** Céline Cappe[1](celine.cappe@epfl.ch), Aaron Clarke[1], Christine Mohr[2], Michael H. Herzog[1]; [1]Laboratory of Psychophysics, Brain Mind Institute, Ecole Polytechnique Fédérale de Lausanne (EPFL), 1015 Lausanne, Switzerland, [2]Faculté des sciences sociales et politiques, Institut de Psychologie, Bâtiment Anthropole, 1015 Lausanne, Switzerland

Newborns have very limited vision and so humans have to learn to perceive. Here, we asked the question whether lifelong learning leads to general visual skills making some observers consistently superior than others in basic visual paradigms. To this end, we tested 40 healthy university students in visual acuity, vernier discrimination, visual backward masking, Gabor contrast detection, and bisection discrimination. If lifelong visual learning leads to generalized visual skills, we expect strong correlations between the paradigms. However, we found that all "interesting" pairwise correlations were non-significant, except for a positive correlation between Gabor contrast detection and visual acuity. The low correlations cannot be explained by intra-observer variability because performance within a given task was highly reproducible. In summary, our study provides evidence that everyday experience shapes perception in a very specific manner.

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23.533 **Learning multiple tasks in roving** Fang Hou[1](hou.130@osu.edu), Zhong-Lin Lu[1], Barbara Dosher[2]; [1]Laboratory of Brain Processes, Department of Psychology, Ohio State University, [2]Memory Attention Perception Laboratory, Department of Cognitive Science, University of California, Irvine

Acquisition of perceptual expertise requires training of perceptual skills with related but different tasks and stimuli. Recent studies found that different stimuli and tasks interact in intermixed training protocols, in some cases eliminating learning (Adini et al. 2004; Yu et al. 2004). The Augmented Hebbian Reweighting Model (AHRM) makes detailed predictions about intermixed training protocols: Randomly mixing multiple stimuli/tasks may make competing and opposing demands on the reweighting structure, or cooperate to support a common weight structure. Optimizing for one task may help, conflict with, or be independent of optimizing for another task, depending on the exact task conditions. Here we test two AHRM predictions: Roving in a dimension separate from the judgment dimension or with tasks that rely on highly localized weight structures should not prevent learning. In experiment 1, two groups were trained in a 45 ± 5 deg Gabor orientation identification task in four spatial frequencies (SFs: 1, 2, 4 and 8 cpd). The SF was fixed within each 80-trial block in the blocked group but intermixed randomly in the roving group. After four sessions of training (2,560 trials), both groups showed substantial improvements in performance with no difference in the magnitude of threshold reduction between the groups. In experiment 2, two groups of participants were trained in a ± 2.5 degree Gabor orientation discrimination task with four base angles (22.5, 57.5, 112.5 and 157.5 deg) at a fixed SF (2 cpd). The base angle was fixed within each 80-trial block in the blocked group but randomized in the roving group. Participants in both groups improved their performance for all base angles. Although the thresholds of the roving group were higher early in learning, the two groups reached the same asymptotic thresholds following 2,560 trials of training. The results are consistent with the predictions of the AHRM.

Acknowledgement: NEI grant EY017491

23.534 **Perceptual Learning of Facial Expressions** Hisa Hasegawa[1](hasegawa.hisa@gmail.com), Hideyuki Unuma[2], Philip J. Kellman[3]; [1]Chubu Gakuin University, [2]Kawamura Gakuen Woman's University, [3]University of California, Los Angeles

Perceptual learning (PL) facilitates picking up structural information of patterns (Gibson, 1969; Kellman, 2002). Recent work suggests that Perceptual Learning Modules (PLMs), consisting of many short speeded classification trials, can accelerate picking up structural information in ecological situations (e.g., Kellman, Massey & Son, 2010). In the present study, we examined whether PLMs facilitate pick up information of facial expressions. The experiment consisted of pretest, PL interventions, and posttest. The task in pretest and posttest was visual search for a facial expression target, which was one of 6 basic emotion categories, among neutral face distractors. Materials were photos of facial expressions. All photo sets in pretest, PL interventions, and posttest were different from each other. We tested for effects of two PL interventions. One was an Emotion PLM and the other was an Identity PLM. In the Emotion PLM, participants were required to classify the emotion of a target person in the display. Choices were 6 photos in 6 emotion categories expressed by other person. In the Identity PLM, observers were required to select the same person of other facial expressions. Each observer received 360 learning trials, given in 10 blocks of either the Emotion PLM or Identity PLM. The primary dependent measure was improvement of search efficiency or slope in the visual search task from pretest to posttest. Results showed that the search slope difference from pretest to posttest in the Emotion PLM condition was significantly greater than the difference in Identity PLM condition. Emotion category also significantly affected search slope. These results suggest that (a) information pick up from facial expressions can be improved in only a few hundred trials, (b) that this improved ability transferred to novel situations, and (c) that fluency in pick up information can be improved especially in fear, anger, and sadness categories.

23.535 **Right brain damage failures of perceptual updating in ambiguous figures.** Elisabeth Stoettinger[1](estoettinger@uwaterloo.ca), James Danckert[1], Britt Anderson[1,2]; [1]University of Waterloo, Department of Psychology, [2]Centre for Theoretical Neuroscience, University of Waterloo

Every day we face the world with beliefs about the rules that govern our environment and what will happen if we take particular actions. When incoming information does not match our predictions, we either need to abandon or update these beliefs. There is accumulating evidence that the right hemisphere is responsible for processing the statistical properties of an uncertain environment, which is important for building accurate representations of our environment, and adapting those representations when necessary. However, mental models may be more than 'look-up tables' of conditional probabilities. Hence, updating failures should also be found when probability learning is less critical. To evaluate this hypothesis, we used a series of pictures that were based on well-known ambiguous figures (e.g., rabbit/duck). Participants saw pictures of unambiguous objects (e.g., rabbit) that incrementally changed over successive presentations to eventually show different unambiguous figures (e.g., duck). The point of transition from reporting the first object to reporting the second, provided an index of updating. RBD patients (n = 16) took significantly longer to switch their reports from the first unambiguous picture (e.g., "it is a rabbit") to the second (e.g., "now it is a duck") than did healthy controls (n = 18) [$F(1,31) = 22.55$, $p < .001$, h2 = .42]. This failure of updating occurred over a short time scale (15 pictures) and was not dependent on statistical learning. Other tests confirmed that results were neither due to a higher tendency to perseverate nor due to general cognitive impairment of the RBD patients. These findings are in accordance with a more generic role for the right hemisphere in model building and updating beyond what comes from the simple amalgamation of probabilities.

Acknowledgement: CIHR

3D perception: Shape from shading and contours

Saturday, May 11, 8:30 am - 12:30 pm

Poster Session, Vista Ballroom

23.536 **Inferring Shape from Shading Flow: light source(s) as an emergent property** Benjamin Kunsberg[1](bkunsberg@gmail.com), Steven Zucker[2]; [1]Applied Mathematics Program, Yale University, [2]Department of Computer Science, Yale University

The inference of shape from shading information depends on the light field, which is initially unknown, sometimes impossible to estimate from the image, and inconveniently inconsistent with priors on its position. We address this problem directly by analytically solving for all surface and light source pairs for every image patch, and then use boundary information to select the correct pair at each patch. Although the work is mathematical, it is motivated by neurobiological constructs. Just as columns of orientation-ally-selective neurons indicate all possible "edge" directions at a point, we derive an analogous column for surface patches. Curvature-based conditions indicate how edges fit together; now surface properties indicate how the patches fit together. Finally, surface curvature information from the boundary "selects" a consistent global surface across all patches, and the light source position(s) emerge naturally. Technically, covariant derivatives of the shading flow "cancel out" the local light source directions in our irradiance equations, and calculations equate the shape operator, dN, uniquely to image properties. Our only assumptions are Lambertian shading, locally constant albedo, and smooth surfaces. dN can be interpreted in terms of curvature selective cells in V4. Solving these equations leads to an infinite surface solution set (a local fiber analogous to an orientation column) parametrized by surface gradient. Each member of the fiber cor- responds to a different local surface/light source configuration. The global problem involves picking a single surface from each fiber, which starts with normal curvature information from the boundary (as viewed from the image) and propagates inwards. Tests confirm proof-of- concept. Summary: shape from

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shading flows is an intermediate-level visual inference analogous to curve inference. Light sources are an emergent property of finding global solutions, and hence need not be represented explicitly in the early visual system.

Acknowledgement: NSF, NIH, AFOSR

23.537 When Shading Flows With Color: Grounding Shape and Material Inference

Emma Alexander[1](emma.alexander@yale.edu), Daniel Holtmann-Rice[1], Steven Zucker[1]; [1]Department of Computer Science, Yale University

The image formation process confounds surface property changes with lighting and geometric variations: are intensity variations material or shading induced? Normally it is assumed that both need be estimated concurrently, but as yet there is no physiological evidence for this in early vision. We seek, instead, to find an approximation to the inverse map that separates material from shading variations robustly (i.e., with high probability) and in a neurobiologically-plausible manner. Formally, we focus on the spatial co-variation of shading and spectral information. When changes are material, consistent co-variation (across projected spatial coordinates) is expected; when changes are due to shading and shadowing, one expects inconsistent co-variation. We propose that consistency is defined in terms of shading and color flows, subject to the condition that color flows do not contain luminance information. We show that (i) these conditions are realized by double-opponent (red/green; blue/yellow), orientation-selective operators locally; (ii) that these operators signal iso-hue directions; and (iii) that global flows obtained from them predict important aspects of the perception of material vs. shading variation over a surface neighborhood. This suggests a fundamental role for double-opponency very different from color edge detection: the orientationally-selective double-opponent cells in superficial V1 could be providing initial hypotheses about domain partitions within the inverse map. Double-opponent (iso-hue) flows generated in the above manner are technically the color analogue to shading flow information, and ground the initial estimation of shading and material properties. Summary: shading flows aligned with (intensity-invariant) double-opponent color flows are robustly material.

Acknowledgement: NSF, NIH, AFOSR

23.538 Towards a unified explanation of shape from shading and texture

Steven A. Cholewiak[1](Steven.Cholewiak@psychol.uni-giessen.de), Roland W. Fleming[1]; [1]Department of Experimental Psychology, University of Giessen, Germany

The estimation of 3D shape from 2D images requires processing and combining many cues, including texture, shading, specular highlights and reflections. Previous research has shown that oriented filter responses ('orientation fields') may be used to perceptually reconstruct the surface structure of textured and shaded 3D objects. However, texture and shading provide fundamentally different information about 3D shape -- texture provides information about surface orientations (which depend on the first derivative of the surface depth) while shading provides information about surface curvatures (which depend on higher derivatives). In this research project, we used specific geometric transformations that preserve the informativeness of one cue's orientation fields while disturbing the other cue's orientation fields to investigate whether oriented filter responses predict the observed strengths and weaknesses of texture and shading cues for 3D shape perception. In the first experiment, a 3D object was matched to two comparison objects, one with identical geometry and another with a subtly different pattern of surface curvatures. This transformation alters second derivatives of the surface while preserving first derivatives, so changes in the orientation fields predict higher detectability for shaded objects. This was reflected in participants' judgments and model performance. In the second experiment, observers matched the perceived shear of two objects. This transformation alters first derivatives but preserves second derivatives. Therefore, changes in the orientation fields predicted a stronger effect on the perceived shape for textured objects, which was reflected in participant and model performance. These results support a common front-end -- based on orientation fields -- that accounts for the complementary strengths and weaknesses of texture and shading cues. Neither cue is fully diagnostic of object shape under all circumstances, and neither cue is 'better' than the other in all situations. Instead, the model provides a unified account of the conditions in which cues succeed and fail.

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23.539 Perceptual bias in 2D orientation is also present in obliquely-viewed planes

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Biases in perceived 2D orientation are asymmetric in the frontal plane: Deviations from horizontal are exaggerated such that a line of 37° from horizontal appears to be 45° (Durgin & Li, 2011). How flexible is the reference frame within which these biases occur? Last year (VSS2012) we showed that these biases stayed with perceived external horizontal/vertical axes in tilted observers. Here we show that, once depth compression (under-constancy) is taken into account for obliquely-viewed planes, the asymmetrical biases remain. Participants (N = 56) made orientation estimates in four virtual display types. In the first and the last displays, oriented lines appeared on frontal walls. In the two middle displays, line orientations were judged relative to implicit planar axes on a textured vertical surface (side wall) viewed to the left of the observer at a 30° observation angle and on a textured horizontal surface (ground plane) viewed downward at a 30° angle. Orientation estimates were made either with respect to the depth-aligned axis (horizontal on the wall plane; "vertical" on the ground plane) or the frontal axis (vertical on the wall plane, "horizontal" on the ground plane). Once depth compression (factor of 0.73) was taken into account, orientation estimates in both planes showed asymmetric patterns of bias with exaggerated deviations from horizontal axes. In other words, the perceptual orientation bias exists with respect to post-constancy representations of surface orientation. Note that the asymmetrical spatial orientation bias depended on the horizontal/vertical axes of the respective planes rather than the reference axis defined as zero. As in the body-tilt paradigm, the results indicate that the bias is not in the retinotopic coding of orientation, but at a later, post-constancy, processing stage in which orientation is coded in extrinsic coordinates imposed by the visual system.

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23.540 The role of smooth occlusions in the perception of 3D shape from shading

Eric Egan[1](egan.51@osu.edu), James T. Todd[1]; [1]Psychology, The Ohio State University

In natural vision, the luminance in each local region of a matte surface is primarily determined by its local orientation relative to the direction of illumination. When the direction of illumination is unknown, it is still possible to obtain compelling perceptions of 3D shape from shading. In such cases, information about the direction of illumination must be estimated from the image shading. For globally convex smoothly curved surfaces, the set of local regions adjacent to smooth occlusions include a range of local orientations. These varied local orientations result in a subsequently varied set of luminance values for most directions of illumination. The present research was designed to investigate the role of shading near smooth occlusions on observers' 3D shape judgments. Images of shaded matte surfaces were presented together with a set of red and yellow dots that could be moved along a single horizontal scan line with a handheld mouse. Observers were instructed to mark each local depth minimum on the scan line with a red dot and each local depth maximum with a yellow dot. The stimuli consisted of deformed spheres. We examined several different reflectance models and patterns of illumination. The surfaces were presented both in full view or through an aperture that removed the surfaces' smooth occlusions and nearby regions from view while leaving the center of the images untouched. The results of the experiment revealed that observers' shape judgments are closer to veridical when the full surface is in view, but systematic distortions in the apparent shapes of surfaces occurred when viewed through the aperture. These findings suggest that the shading near smooth occlusions plays an important role in estimating 3D shape from shading and that these regions provide the salient information concerning a surface's direction of illumination.

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23.541 Effect of symmetry on perception of 3D shape from stereo and shading

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Symmetry has been found to improve 3D shape discrimination across change in viewpoint and lighting. We tested whether this benefit is due to use of symmetry as constraint for interpreting 3D information from stereo and shading. Observers performed sequential 3D shape discrimination of random, smoothly-curved symmetric objects that were rotated in depth by various amounts (0°-60°). We manipulated the 3D information provided by symmetry by varying the orientation of an object's symmetry plane relative to the direction of viewpoint rotation. Base orientation of the symmetry plane was either horizontal or vertical, and viewpoint rotation was either horizontal or vertical. In Experiment 1, objects were presented in stereo with no shading information. We found that discrimination was better when rotation was perpendicular to the symmetry plane, which causes the symmetry plane to be slanted in depth, than when the rotation was parallel to the symmetry plane, which keeps the symmetry plane aligned with the line of sight. In Experiment 2, objects were presented monocularly with Lambertian shading, and lighting direction was varied from above-left to front-right. Performance was better for objects with a vertical symmetry plane than those with a horizontal symmetry plane with and without viewpoint rotation. In both experiments, symmetry was most advantageous when the constraint imposed by symmetry was complementary to the ambiguity from stereo or shading information.

23.542 **Is there only one sun?** Giacomo Mazzilli[1](gxm947@bham.ac.uk), Andrew J. Schofield[1]; [1]School of Psychology, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK

Prior assumptions about the light source are critical to perceiving Shape-from-shading. Classical studies have shown that the humans tend to perceive objects as lit from above. Nevertheless, more recent studies have demonstrated that the influence of this prior may be weaker than initially thought. In particular, the influence of the lighting prior is negatively correlated with the strength of lighting cues. We explored the human visual systems ability to cope with lighting ambiguities; testing whether the brain adopts a global or local analysis to clarify uncertain cases. Observers made shape judgments for ambiguously shaded disks embedded in complex scenes containing shading and shadows providing cues to the true direction of the illuminant. The ambiguous disks could be either perceived as bumps or dents depending on observers' interpretation of the lighting direction. Scenes were lit by two opposite spotlights such that local lighting cues depended on the test location whereas global cues suggested two opposing light sources. Observations were made at 7 different locations in each scene. The orientation of the shaded disk was set to be one of 8 evenly spaced angles in the 0-360 range. We tested 3 different scene conditions: No articulating structure (to determine observers lighting priors); fully articulated structure (providing both local and global lighting cues) and no local cues structure in which structure elements close to the test location were removed thus removing local lighting cues. We found that strong local lighting cues tend to override priors and therefore to guide observers' perception of shape-from-shading. Where two light sources illuminate the scene, the one illuminating the part of the scene under test determines the percept. Where the two sources illuminate the local area equally the lighting prior dominates as is also the case when the local lighting cues are weak or absent.

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23.543 **Perceived depth from luminance gradient and disparity** Chien-Chung Chen[1, 3](c3chen@ntu.edu.tw), Christopher Tyler[2]; [1]Department of Psychology, National Taiwan University, [2]Smith-Kettlewell Eye Research Institute, [3]Neurobiology and Cognitive Science Center, National Taiwan University

Perceived depth is conveyed by multiple cues, including binocular disparity and luminance shading. Depth perception from 3D-shape-from-shading information depends on the perceptual assumption of the incident light, which has been shown to default to a diffuse illumination assumption (Tyler, 1998, J Inf Sci Tech, 42:319-25). We ask how shading and disparity cues combine for surfaces defined by the joint luminance and disparity modulation of textured sinusoidal luminance gratings. The observers' task was to adjust the binocular disparity of a comparison random-dot stereogram (uniform dot distribution, dot size 2′) to match the perceived depth of a target consisting of the sum of a disparity-modulated sinusoidal luminance modulation (0.5 or 2 cyc/deg, contrast 20%-80%) target and a random dot pattern (contrast 0%-20%) to simulate surface texture and to enhance disparity information in the target stimuli. The target disparity was modulated from 0′-20′ and was either in-phase or in opposite phase with the luminance modulation. Five observers participated. Regardless target spatial frequency, when texture contrast was low (or zero), the perceived target depth increased with the luminance contrast and the perceived concaveness depended on luminance phase but was not affected by the luminance disparity modulation. At high texture contrast, the perceived depth modulation increased linearly with target disparity modulation but was not affected by target contrast. These results validate the idea that a human observer can use the diffuse illumination assumption to perceive depth from luminance gradients alone without making the assumption of light direction. With combined cues, the observer used EITHER luminance shading OR disparity for depth judgment but not both. Such all-or-none behavior suggests that disjunctive mechanisms underlie these two types of information.

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23.544 **Spatio-temporal information is not necessary for generating view-point invariant object recognition during unsupervised learning** Moqian Tian[1](moqiant@stanford.edu), Kalanit Grill-Spector[1,2]; [1]Psychology Dept., Stanford Univ., [2]Stanford Institute for Neuro-innovation and Translational Neuroscience.

To achieve view invariant object recognition it is necessary to bind different 2D views of an object to the same 3D representation. One mechanism that has been proposed is unsupervised learning in which subjects see smoothly changing views of an object, generating spatial and temporal correlations between views that are thought to bind them (Wallis et al. 2001). However, it is unknown if spatio-temporally ordered exposure to object views are necessary for generating view invariant recognition. To address this question we conducted three experiments and tested subjects' ability to learn to discriminate novel 3D computer generated objects across views. During unsupervised learning subjects were exposed to 24 views of novel objects (12 times each). Views of an object appeared either in sequential or random order. Pre- and post- training (~10 minutes apart) subjects performed a discrimination task, judging if two views 90° apart were of the same object or of different objects. In Experiment 1, 14 subjects learned to discriminate views of 3D objects rotated in the image plane. We found a strikingly fast and significant learning effect. Surprisingly, we found no differences in performance across sequential and random learning. In Experiment 2, 20 subjects learned to discriminate views of 3D objects rotated in depth around the vertical axis. Again, we found significant learning and no differences across sequential and random learning. In Experiment 3, we tested if implied motion was key to learning. 10 subjects were similarly trained but for half of the objects, masks were placed between consecutive images to prevent implied motion. We found significant learning effects across all conditions, no differences between masked and unmasked conditions, and a significant improvement for sequential than random training. Overall, our experiments show that unsupervised exposure to 2D views of objects is sufficient to generate view invariant recognition.

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23.545 **Identification of Nonrigid 3D Shapes from Motion Cues in the Fovea and Periphery** Anshul Jain[1](ajain@sunyopt.edu), Katja Doerschner[2], Qasim Zaidi[1]; [1]Graduate Center for Vision Research, SUNY College of Optometry, [2]Department of Psychology & National Magnetic Resonance Research Center, Bilkent University

Jain & Zaidi (2011) in a shape-from-motion paradigm showed that human observers are as good at making categorical judgments (fat vs thin) for nonrigid shapes as they are for rigid shapes based solely on motion cues. They showed for the first time that an explicit rigidity assumption was not required for extracting 3D shape from motion cues, at least for simple categorical judgments. In the current study we examined whether a more objective task such as shape identification would reveal an advantage for rigid objects, thus lending support to the rigidity assumption hypothesis. Stimulus consisted of point-light versions of ellipsoids that contained three bumps or dimples at three locations on the surface, thus leading to eight possible shapes. The ellipsoids were either rigid or deformed smoothly in the depth plane or the image plane. The stimuli were presented either at the fovea or at 4 deg. eccentricity after adjusting for the cortical magnification factor. Observers (N=4) performed an 8AFC shape-identification task and we measured their performance as a function of bump/dimple height/depth. Observers' performance was identical for rigid and the two nonrigid ellipsoids both at the fovea and under peripheral viewing, thus providing further evidence against an explicit rigidity assumption. Observers' performance in the periphery was comparable to their performance in the fovea after adjusting for cortical magnification factor. Our results suggest that extraction of 3D shape from motion cues in the periphery is limited by mechanisms that extract optic flow and lie lower in the visual system hierarchy than by higher level mechanisms that process the optic flow to extract 3D shapes. We propose multi-scale first-order optic flow analyses (div, def and curl) to extract both 3D shapes and deformations.

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23.546 **The kinetic depth effect for vision and haptics** J. Farley Norman[1](Farley.Norman@wku.edu), Flip Phillips[2], Jacob Cheeseman[1], Kelsey Thomason[1], Cecilia Ronning[1], Autum Calloway[1], Davora Lamirande[1]; [1]Department of Psychology, Western Kentucky University, [2]Department of Psychology, Skidmore College

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It has long been known that motion facilitates the visual perception of 3-D object shape, particularly when surface texture or other trackable object features are present (e.g., Wallach & O'Connell, 1953; Braunstein, 1966; Todd et al., 1985; Norman, Lee, Phillips, et al, 2009). Conventional models of structure-from-motion require the presence of texture or trackable object features in order to recover 3-D structure. Is the facilitation in 3-D shape perception similar in magnitude when surface texture is absent? On any given trial in the current experiment, 30 observers were presented with a single randomly-selected bell pepper (for 12 seconds) and were required to indicate which of 12 simultaneously visible bell peppers possessed the same shape. The initial single pepper's shape was defined either by boundary contours alone (i.e., presented as a silhouette), specular highlights alone, specular highlights and boundary contours, or volumetric texture. In addition, there was a haptic condition: in this condition, the observers felt (but could not see) the initial single object for 12 seconds. For both the visual and haptic conditions, motion (rotation in depth or active object manipulation) was present in half of the trials and was not present for the remaining trials. A 2x5 split plot ANOVA demonstrated that the effect of motion was quantitatively similar for all of the visual and haptic conditions ($F(1, 25) = 70.8$, $p < .000001$) -- the observers' performance was 93.5 percent higher in the motion or active haptic manipulation conditions (when compared to the static conditions). The current results demonstrate that deforming specular highlights or boundary contours facilitates 3-D shape perception as much as the motion of objects defined by surface texture. The current results also indicate that the improvement with motion that occurs for haptics is similar in magnitude to that which occurs for vision.

23.547 **Shape From Very Little: The Visual and Haptic Kinetic Depth Effect** Flip Phillips[1](flip@skidmore.edu), Farley Norman[2], Kriti Behari[1], Kayla Kleinman[1], Julia Mazzarella[1]; [1]Skidmore College, Neuroscience & Psychology, [2]Western Kentucky University, Psychology

Our companion poster at this conference (Norman, Phillips, et al. 2013) examines the oft noted phenomenon that structure from motion facilitates 3D shape perception. Traditional structure from motion algorithms rely on a manifold of trackable features to recover three dimensional shape, but the simple deformation of a boundary silhouette is often enough to make reliable judgements about object shape. Furthermore, active haptic explorations of objects provides a similarly rich amount of information for shape discrimination, but again, reliable discriminations can still be made with passive encounters with objects. In this work we use a series of shapes, (nee 'glavens') which are scaleable in relative complexity, to examine subjects' ability to identify shapes with various amounts of impoverished visual and tactile information. We chose to present the stimuli via boundary contours, specular highlights, solid texture, or haptically. In each condition block, the objects were presented with or without motion or actively / passively scanned in the haptic condition. On a given trial, a randomly selected glaven was presented for approximately 12 seconds via computer graphics. The subject then identified the presented glaven from a 'lineup' array of 3D-printed object instances. Results for the various presentation conditions were identical to those in our companion poster — basically that motion and active haptic exploration facilitated identification by similar amounts. Furthermore, since our objects were scaled in complexity, we were able to establish that the magnitude of the object confusion error decreased in the motion / active exploration conditions (e.g. errors in identification were usually with objects of similar complexity).

23.548 **The Influence of Affect on 2D Pattern Perception** Michelle L. Fowler[1], Elliot Lockerman[2], Andrea Li[2]; [1]Neuropsychology Doctoral Subprogram, Graduate Center, City University of New York, [2]Department of Psychology, Queens College, City University of New York

The underlying mechanisms used to process 2D information to form a unified 3D percept remain largely unknown. Previous work in our lab has shown that accurate 3D perception of textured surfaces depends on the presence of specific patterns of orientation flows in the image. Recent research has shown that other neural processes such as affective state may influence the visual perception of oriented patterns. For example, Bocanegra and Zeelenberg (2009) found that relative to neutral face stimuli, fearful face stimuli can augment sensitivity to orientation of low spatial frequency gratings and decrease sensitivity to orientation of high spatial frequency gratings. The current study aims to extend these results by investigating 1) how the effects of affect on orientation perception might generalize across face databases, and 2) how affect might alter the perception of orientation in more complex patterns and ultimately, patterns containing orientation flows that convey 3D shape. Using the Radboud face database, we presented affective fear versus neutral face primes before grating and plaid stimuli and measured orientation sensitivity to both low (2cpd) and high (4cpd) spatial frequency patterns. Preliminary results suggest that fearful primes, relative to neutral primes, may increase orientation sensitivity to low frequency stimuli and reduce orientation sensitivity to high frequency stimuli, as was found in Bocanegra and Zeelenberg (2009), and that these results appear to generalize to the Radboud face database. However, this pattern of results appears to occur only for vertical grating stimuli. Fearful primes do not appear to affect orientation sensitivity to horizontal gratings or horizontal-vertical plaids. Implications for the perception of orientation flows required for 3D shape perception will be discussed.

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23.549 **Painted objects influence perceived depth of 3-D surfaces they are painted on – Two examples from Patrick Hughes's art pieces** Thomas V. Papathomas[1,2](papathom@rci.rutgers.edu); [1]Laboratory of Vision Research, RuCCS, Rutgers University, [2]Department of Biomedical Engineering, Rutgers University

Introduction: Patrick Hughes invented reverspectives (RP): piece-wise planar surfaces of volumetric solids jutting out from the wall with their small parts nearer to the viewer than their large bases. Hughes uses linear perspective to paint realistic scenes - on these surfaces - that compete against the physical geometry. Namely, the painted scenes suggest that physically nearer parts are further than physically distant parts. RPs cause a vivid illusory motion in two dual conditions: (a) RPs appear to move for viewers who move in front of them. (b) When rotated, RPs appear to rotate in the opposite direction than the physical direction for stationary viewers. Because the raw surfaces contain RP geometry, they induce the illusion even when unpainted. VARIATIONS: Forced perspectives (FP): The small parts are further than large parts and the scene is now painted to be congruent with the physical geometry. FPs recede into the wall, and they appear stationary for moving viewers. Finally, conventional planar perspectives (PP) are painted on a flat canvas and they appear to turn for moving viewers under certain conditions, but less vividly than reverspectives. NOVEL PERSPECTIVE TECHNIQUE: Patrick Hughes has designed art works ["Forced into Reverse Perspective" (2008), "Day-dreaming" (2008)] that contain all three types of perspective (RP, FP and PP), painted on a single piece-wise planar surface, itself forming a geometric RP. He paints the surface to break it into individuated objects. A subset of these objects are painted in RP, hence they appear to move; others are painted in PP producing less vivid motion; still a third category of objects are painted in FP and appear stationary. Overall, viewers perceive individual objects that defy the surface geometry and move in a wide variety of patterns, as confirmed by experiments, even though the unpainted surface would move in only one direction.

23.550 **Three-dimensional depth illusions in schizophrenia and bipolar disorder** Yushi Wang[1](wangy12@umdnj.edu), Brian Keane[1,2,3], Steven Silverstein[1,2], Thomas Papathomas[3,4]; [1]University Behavioral HealthCare, UMDNJ , [2]Department of Psychiatry, UMDNJ—Robert Wood Johnson Medical School, [3]Center for Cognitive Science, Rutgers University, New Brunswick, [4]Department of Biomedical Engineering, Rutgers University, New Brunswick

Purpose: People with schizophrenia are less likely to perceive physically concave objects as convex (as in the hollow mask illusion). Are reduced depth illusions specific to schizophrenia or do they also occur in other illnesses in which psychotic symptoms occur, such as bipolar disorder? Method: We compared a bipolar group (N=13) to previously examined healthy control (N=25) and schizophrenia (N=30) groups. Subjects made convexity judgments about 5 physical objects. Two were concave scenes ("reverspectives"), two were concave faces, and one was a convex face (catch stimulus). A reverspective and a concave face were painted with life-like texture; the remaining objects were uniformly colored. All five objects were viewed twice—once monocularly with the subject moving left-right (to create motion parallax) and once stereoscopically with the subject stationary (to isolate the role of binocular disparity). For each viewing, subjects were probed every 12 seconds over 2 minutes on whether the object appeared convex or concave. Results: There were no significant differences between the three subject groups in perceiving the catch stimulus ($p>.4$). For concave objects, schizophrenia patients gave more accurate (veridical) responses than controls ($p<.05$) but bipolar patients did not differ significantly from either of the other groups ($p>.12$). However, the group comparisons depended on symptoms: The 15 most psychotic schizophrenia patients clearly differed from the bipolar and control groups ($p<.05$); the 15 least psychotic patients differed from neither the bipolar nor control group. None of the group differences depended on texture, object-type or viewing condition ($ps>.24$). Conclusions: We conclude that concave objects produce fewer depth illusions in schizophrenia than bipolar disorder but only if schizo-

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phrenia patients are sufficiently psychotic. We also found that the group difference is constant across different object types and viewing conditions, suggesting that positive symptoms may disrupt a generic convexity prior.

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Spatial vision: Models

Saturday, May 11, 8:30 am - 12:30 pm

Poster Session, Vista Ballroom

23.551 Rapid Assessment of Contrast Sensitivity with Mobile Touch-screens

Jeffrey B. Mulligan[1](jeffrey.b.mulligan@nasa.gov); [1]NASA Ames Research Center

The availability of low-cost high-quality touch-screen displays in modern mobile devices has created opportunities for new approaches to routine visual measurements. Here we describe a novel method in which subjects use a finger swipe to indicate the transition from visible to invisible on a grating which is swept in both contrast and frequency. Because a single image can be swiped in about a second, it is practical to use a series of images to zoom in on particular ranges of contrast or frequency, both to increase the accuracy of the measurements and to obtain an estimate of the reliability of the subject. Sensitivities to chromatic and spatio-temporal modulations are easily measured using the same method. We will demonstrate a prototype for Apple Computer's iPad/iPod/iPhone family of devices, implemented using an open-source scripting environment known as QuIP (QUick Image Processing, http://scanpath.arc.nasa.gov/quip/).

23.552 Cortical surface structure predicts extrastriate retinotopic function

Noah C Benson[1,2](nbe@sas.upenn.edu), Omar H Butt[1], Sandeep Jain[1], David H Brainard[2], Geoffrey K Aguirre[1]; [1]Department of Neurology, University of Pennsylvania, Philadelphia, PA 19104, [2]Department of Psychology, University of Pennsylvania, Philadelphia, PA 19104

We have shown that surface topology can predict retinotopic organization in area V1 (Benson et al., 2012). Here we extend this approach to extrastriate cortex (V2, V3) by creating an anatomical registration space in which a model of visual area organization may be fit to retinotopic mapping (RM) data. Sweeping-bar RM (10° eccentricity) was conducted in 19 subjects (548 TRs total, 3mm voxels). Anatomical images were mapped to FreeSurfer's fsaverage pseudo-hemisphere and then flattened. Cortical flattening produces geometric distortions. To apply the banded, double-sech retinotopic model proposed by Schira et al. (2010), we created a registration of the aggregate RM data (across subject, left and right hemisphere) to the Schira model using a spring simulation. Vertices were treated as point masses connected by ideal springs. The springs drove each vertex to minimize the difference between its retinotopic mapping value and the corresponding position in the Schira model while preserving the local topography of the cortical surface. The Schira model was then fit to RM data within the resulting registration space. Schira model parameters for RH and LH data were virtually identical, suggesting that RH and LH can be treated as a single hemisphere in the registration space. The median absolute error across V1, V2, and V3 for all subjects and vertices was 12.6°/0.9° of polar angle/eccentricity for the left and 18.8°/0.9° of polar angle/eccentricity for the right hemisphere. The same errors, calculated using a leave-one-out paradigm in which function was predicted from only the anatomy of the target hemisphere, were 31.0°/1.1° of polar angle/eccentricity (LH), and 29.4°/1.2° of polar angle/eccentricity (RH). Our registration-based method combines anatomy and functional data to predict the retinotopic organization of extrastriate visual cortex. Using the method, we show that the retinotopic organization of extrastriate cortex may be well predicted by cortical surface topology alone.

Acknowledgement: R01 EY020516-01A1, PA CURE Grant

23.553 Differential Properties of Narrowly-Tuned and Broad Temporal Channels

Eleanor O'Keefe[1](emayokeefe@gmail.com), Yeon Jin Kim[3], Edward Essock[1,2]; [1]Department of Psychological & Brain Sciences, University of Louisville, [2]Department of Ophthalmology & Visual Science, University of Louisville, [3]Department of Ophthalmology, McGill University, QC, Canada

The visual system contains multiple narrowly-tuned spatial frequency channels. In contrast, only two broad temporal channels are typically reported ("sustained" and "transient"). However, recent broadband masking experiments show multiple, narrow temporal channels in addition to the two broadly-tuned mechanisms (Kim and Essock, VSS, 2010). In the present work, we investigated the temporal tuning of flicker masking and cross-orientation masking (XOM) to better characterize these two types of temporal filtering. In the first experiment, test stimuli were high-speed or low-speed horizontal Gabor patches, which were masked by uniform-field flicker at varied temporal rates (2 to 20 Hz). The tuning of this flicker masking was measured for four test orientations (0°, 45°, 90° or 135°) to assess whether an anisotropy exists in masking by spatially unpatterned fields. In the second experiment XOM was examined using broadband masks consisting of 1/f broadband oriented noise that was either iso- or cross-oriented, and temporal tuning of masking was assessed. Flicker masking increased with temporal rate and showed, at best, a weak peak at ~10 Hz. Most importantly, flicker masking was anisotropic, with thresholds for horizontal test gratings higher than those of other test orientations (horizontal effect), even though there was no orientation information present in the mask. In the broadband masking conditions, temporal tuning shows two peaks: one around 10 Hz attributed to the high-speed ("transient") mechanism, and one attributed to the narrowly-tuned suppression pools reported previously. We suggest that the effects of many types of masking are pooled at the level of the cortical filters (perceptual channels) and that the anisotropy observed is due to differential weighting of the output of these normalization pools upon filters of different orientations (rather than anisotropic weighting of the inputs to these pools from filters of different orientations).

23.554 A model of detectability across the visual field

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Accurately characterizing peripheral vision is a fundamental goal of vision science. Additionally, predicting the detectability of a peripheral target in healthy adults has important implications for understanding visual dysfunction, as well as in designing displays. Here, we propose a model of detectability across the visual field. Our model filters the target image by the optics, samples the image with an array of model ganglion cells with Difference of Gaussians receptive fields, applies a rule similar to d'-summation, and then converts the result into a detection threshold. If the background is not uniform, that threshold is adjusted by taking the local luminance, spatial uncertainty, and background contrast power affecting the target template into account. This model (1) takes the physiology and anatomy of early vision into account, (2) is consistent with the extant psychophysical literature, (3) has the flexibility to account for any target/background combination, and (4) is computationally fast. In this study, we measured contrast detection thresholds for three targets (Gabor, Gaussian, Edge) at four eccentricities (0, 2.5, 5, & 10°) along the horizontal meridian on a uniform background. In this case, the modeled parameters are the foveal center size for the ganglion cell receptive fields, the size of the center-surround scalar, the center weight, the exponent for summation, and the internal noise. The first three parameters have direct analogs in the physiological literature, while the remaining two have been examined psychophysically. All thresholds are well fit by the model. Additionally, we found that our model provides a good fit for the ModelFest data set. The parameter estimates are within established limits defined by previous literature. Thus, we are able to predict detection thresholds for multiple targets on a uniform background. This model can serve as a framework for models of other phenomena such as visual search, attention, or learning.

Acknowledgement: EY02688

23.555 External noise paradigms, contrast sensitivity and aging

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At least three studies (Bennett et al., 1999; Spérenza et al., 2001; Pardhan, 2004) have used external noise paradigms to investigate the cause of contrast sensitivity losses due to healthy aging. These studies have used noise that was spatiotemporally localized on the target. Allard and Cavanagh (2011) have recently shown that the processing strategy can change with localized noise thereby violating the noise-invariant assumption, which compromises the application of external noise paradigms. The goal of the present study was to reassess the cause of age-related contrast sensitivity losses using external noise that is spatiotemporally broad (i.e. full-screen, continuously displayed dynamic noise). Contrast thresholds were measured for two age groups, young (n = 20, mean = 24 years) and older adults (n = 20, mean = 69 years), for 3 spatial frequencies (1, 3 and 9 cpd) and 3 noise conditions (noise-free, local noise and broad noise). At the lowest spatial frequency, the results drastically differed depending on the noise condition: age-related contrast sensitivity losses were attributed to the internal equivalent noise when using broad noise (i.e. age did not affect contrast thresholds in broad noise) and, consistent with previous studies, due to calculation efficiency with local noise (i.e. similar age-related contrast threshold effects in noise-free and local noise). At the two highest spatial frequencies, the results were similar with local and broad noise: the sensitivity loss was mainly due to lower calculation efficiency, consistent with 2 previous studies. These results show that the interpretation of external noise paradigms can drastically differ depending on the noise type suggesting that external nose paradigms should use spatiotemporally broad external noise, like internal noise, to avoid triggering a processing strategy change. Contrary to all previous studies, we conclude that healthy aging does not affect the calculation efficiency of detection processing at low spatial frequencies.

Acknowledgement: This research was supported by NSERC discovery fund and by the NSERC-Essilor industrial research chair awarded to Jocelyn Faubert.

23.556 **Perception is biased by a preceding decision**

Toni Saarela[1](saarela@sas.upenn.edu), Alan Stocker[1]; [1]Department of Psychology, University of Pennsylvania

When making two consecutive perceptual decisions about a single visual stimulus, is an observer's second decision biased by the first decision? We tested a probabilistic model of conditioned perception (Stocker & Simoncelli, 2008) that hypothesizes that such biases emerge from the observer's goal to remain self-consistent between decisions. The stimulus comprised 52 Gabor patches (spatial frequency: 8 cycles/deg, uniform orientation) placed on a grid with jittered locations and presented foveally for 250 ms. Observers first performed two orientation discrimination tasks in isolation. Task 1: The observer compared the stimulus orientation to a reference orientation indicated by a pair of lines. Task 2: Two Gabor stimuli were presented consecutively. The observer compared the second stimulus orientation to the first one. To test the model, we estimated noise parameters for the model from these discrimination data (individually for each observer) and computed the model's predictions for performing the two tasks sequentially. In the sequential task, the observer first compared the stimulus orientation to the reference and then compared the orientation of a second stimulus to the first. The model observer, when making the second decision in the sequence, discards the sensory evidence for any orientation inconsistent with the first decision, and is thus more likely to respond "counter-clockwise" in the second task after responding "clockwise" in the first task, and vice versa. This predicts both a repulsive shift and a change of slope in the psychometric curve. An alternative model, which optimally uses all the available evidence, predicts a smaller shift and no change in slope. The observers' second decision was consistently biased by the first one. The measured psychometric curves were well predicted by the conditioned perception model and were distinct from the predictions of the alternative model. Past decisions thus condition the use of sensory information in subsequent perceptual tasks.

23.557 **Modeling Hyperacuity Data with a Hierarchical Neural Vision Network and Modified Hebbian Learning**

Harald Ruda[1](h.ruda@neu.edu), Ennio Mingolla[1], Stephen Grossberg[2], Arash Yazdanbakhsh[2]; [1]Computational Vision Laboratory, Northeastern University, [2]Center for Computational Neuroscience and Neural Technology (CompNet), Boston University

Visual hyperacuity enables an observer to make accurate judgements of the relative positions of stimuli when the differences are smaller than the size of a single cone in the fovea. Hyperacuity can be used as a gauge for testing various characteristics of the visual system, and it can also be used as a stringent test for models of the visual system. A variant of the Boundary Contour System (BCS) is here used to address previously unexplained psychophysical hyperacuity results involving contrast polarity, stimulus separation, and sinusoidal masking gratings. Two-dot alignment thresholds were studied by Levi & Waugh (1996), who varied the gap between the dots, with same and opposite contrast polarity with respect to the background, and also with and without a broadband sinusoidal grating of different orientations. They found that when the gap between the dots is small (6 arcmin), different patterns of results are obtained for the same and different contrast polarity conditions. However, when the gap is large (24 arcmin), the same pattern was obtained irrespective of contrast polarity. The simulations presented here replicate these findings, producing the same pattern of results when varying the gap between the dots, with same and opposite contrast polarity with respect to the background, and also with and without a broadband sinusoidal grating of different orientations. The vision model used (BCS) is able to produce these results because it includes stages of contrast insensitivity (complex cells), spatial and orientation competition, and long-range completion. A novel aspect of the model is the use of sampled field processing, which simplifies the model's description in terms of equations. In addition, modified Hebbian learning and a neural decison module are proposed as mechanisms that link the vision model's outputs to a decision criterion. All model parts are biologically plausible and have physiological correlates.

Acknowledgement: Supported in part by CELEST, an NSF Science of Learning Center (NSF SBE-0354378)

23.558 **The Psi-marginal adaptive method (or: how to give nuisance parameters the attention they deserve, no more and no less).**

Nicolaas Prins[1](nprins@olemiss.edu); [1]Department of Psychology, College of Liberal Arts, University of Mississippi

Adaptive testing methods serve to maximize the information gained regarding the values of the parameters of a psychometric function (PF). Such methods typically target only one or two ('threshold' and 'slope') of the PFs four parameters while assuming fixed values for the 'nuisance' parameters ('guess rate' and 'lapse rate'). However, due to some redundancy among the parameters of the PF (e.g., Prins, J. Vis. 12(6):25, 2012) bias in parameter estimates results when the assumed values for the nuisance parameters do not match the generating values. This bias may be alleviated somewhat when observations are fitted in a subsequent procedure in which the nuisance parameters are allowed to vary. When this is done however, the uncertainty regarding the values of the nuisance parameters (not addressed by the adaptive method) contributes to the uncertainty in the values of the parameters of interest. Here I propose the Psi-marginal adaptive method which addresses this issue specifically. The method is based on Kontsevich & Tyler's (Vision Res. 39(16):2729-37, 1999) Psi-method. However, in the proposed method a posterior distribution defined across all parameters of unknown value is maintained. Critically, selection of stimulus intensities is based on the expected information gain in the marginal posterior distribution defined across the parameters of interest only. The appeal of this method is that it will target nuisance parameters but only when doing so maximizes the expected information gain regarding the values of the parameters of interest. The method is extremely flexible: any combination of the PF's four parameters may be included in the posterior and any combination of those included may be treated as nuisance parameters. Simulations indicate that use of the Psi-marginal method results in smaller bias and higher precision in threshold and slope estimates compared to the original Psi method.

23.559 **Empirical study of the role of aesthetic issues in spatial composition, scene perception architecture, spatial-taxon distribution and entry-level object labels**

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Purpose: Artists specializing in two-dimensional media choose the most aesthetically appealing spatial composition and scene architecture for the subject of their artwork. Palmer et al (2008) discovered a strong inward and center facing aesthetic bias. Barghout et al (2010, 2008) found that a model of scene architecture composed of hierarchically nested spatial-taxons was consistent with the "entry level" object labels proposed by Jolicour et al (1984). This model followed a rank-frequency distribution that was independent of image content and image subject numerosity, and was consistent with a law of least effort. In this study, we explored if these established findings were invariant under aesthetic and non-aesthetic spatial composition condtitions. Methods: Paper surveys consisting of black and white drawings of inward facing and outward facing figures were distributed. Participants were asked to draw an 'x' on the center of the subject of the image. Participants were asked to rank the aesthetic of the image using a Likert scale and write down a few words to describe the image. An N by M factorial design was used, where N represented single vs. dual subject composition and M represented aesthetic vs. non-aesthetic configuration. K-means clustering analysis determined spatial-taxon designation of the images as defined by Barghout et al (2010,2008). Rank-frequency distributions for spatial-taxons and corresponding word labels were fit using linear regression analysis. Results: Our dataset of annotated images with empirically derived spatial-taxons and their relative frequencies provides insight into the interaction effects between aesthetic configuration, spatial-taxon organization of scene architecture, and word labels. The frequency distribution of spatial-taxons for both aesthetic and non-aesthetic dual-subject figures followed a Gaussian distribution while single-subject figures with a non-aesthetic configuration followed an inverted Gaussian frequency distribution. Keywords: aesthetic preference, spatial composition; rectangular frame, spatial-taxon, scene perception, entry-level categories, law of least effort, object recognition

 See page 3 for Abstract Numbering System

Saturday Afternoon Talks

Development

Saturday, May 11, 2:30 - 4:15 pm
Talk Session, Royal Ballroom 1-3
Moderator: Pawan Sinha

24.11, *2:30 pm*

Rapid Development of Feed Forward Inhibition Drives Emergence of Visual Alertness

Matthew Colonnese[1](colonnese@gwu.edu); [1]Pharmacology and Physiology, George Washington University

The generation of appropriate cortical network states is a key regulator of visual perception and plasticity, but their role during development is poorly characterized. We have shown that human preterm infants and pre-eye opening rats undergo a rapid maturation of network states just before the onset of visual experience. This change results in a massive down regulation of visual responses, shifting them from all-or-none oscillatory bursts, to graded responses capable of processing visual input. Here we test the hypothesis that this maturation is the rapid emergence of cortical activation, or 'active', states. Using in vivo current clamp and polytrode recordings in visual cortex of awake, head-fixed neonatal and infant rats, we find that cortical activation, defined by persistent membrane depolarization during waking, emerges suddenly 1-2 days before eye-opening. The amplitude of activation remained constant between emergence and adulthood, though stability and duration of depolarization gradually increased. This switch in network properties was responsible for the down-regulation of visual responses as light began to evoke active states rather than supra-theshold plateau potentials observed before the switch. Reducing GABAA currents just after the switch eliminates activation and reverts activity to immature patterns. Measurement of the timing and amplitude of inhibitory and excitatory currents by voltage clamp showed the rapid development of fast feed-forward inhibition at this time. In total we have identified, for the first time, a specific role for changes in inhibitory circuitry in the developmental regulation of cortical activity. This change effectively divides visual cortex development into two clear phases--an early pre-visual period concurrent with spontaneous retinal waves and the establishment of retinal topography, and a late period linked to the onset of pattern vision, visual exploration and the onset of experience-dependent plasticity—that each have unique computational characteristics.

24.12, *2:45 pm*

Blindness subtly alters the distant functional connectivity of dorsal and ventral extra-striate cortex

Omar H Butt[1](obutt@mail.med.upenn.edu), Noah C Benson[1,2], Ritobrato Datta[1], Geoffrey K Aguirre[1]; [1]Department of Neurology, University of Pennsylvania, [2]Department of Psychology, University of Pennsylvania

Resting state correlations are reduced between matched extrastriate regions in the blind (Watkins et al, 2012), and fine-scale connectivity is attenuated between the striate cortices (Butt et al, 2012 VSS). Here, we explore whether blindness alters the fine-scale connectivity and regional quadrantic (dorsal/ventral) relationship of extrastriate areas. 12 sighted and blind, age-matched participants were scanned (150 or 160 TRs BOLD fMRI, TR=3, 3mm voxels) under constant darkness. Within FreeSurfer template space each vertex was assigned a visual area (V2 and V3, dorsal and ventral) and retinotopic mapping value based on cortical surface anatomy (Benson et al., 2011 & 2013, VSS). We calculated a "quadrantic ratio", which relates the functional connectivity within the dorsal and ventral halves of visual areas to the connectivity between the two dorsal and two ventral regions. We next obtained fine-scale cross-correlation matrices (5595×5595 cells), which compare each extrastriate vertex to every other. These matrices were decomposed into a local-topography component (in which connectivity could be modeled as a Gaussian spread of correlation about two vertices that share retinotopic assignment) and a residual component. The blind had decreased functional connectivity between right and left V2 and V3, and a significantly decreased "quadrantic ratio" within ($p=0.009$) and between hemispheres ($p=0.037$). While there were no group differences in fine-scale extrastriate connectivity as characterized by local topography ($p=0.96$), the residual matrices did differ between groups ($p=0.026$). A surprising finding is that the local spread of correlation between topographically matched extrastriate points is unaltered in blindness. Vision is needed, however, to develop or maintain the link between the dorsal and ventral quandrants of a visual area and contributes to fine-scale correlations between visual areas that cannot be characterized by a local point-spread function.

Acknowledgement: R01 EY020516-01A1 PA CURE Grant

24.13, *3:00 pm*

Development of Contrast Sensitivity Following Extended Congenital Blindness

Amy Kalia[1](akalia@mit.edu), Luis Lesmes[2], Michael Dorr[2], Tapan Gandhi[1], Garga Chatterjee[1], Peter Bex[2], Pawan Sinha[1]; [1]Department of Brain and Cognitive Sciences, M.I.T., [2]Schepens Eye Research Institute, Harvard Medical School

We report on the recovery of vision in patients who were treated for very early onset (<1 year) cataracts after long-term deprivation (8-19 years). Previously reported cases of sight restoration either had significant visual experience for the first few years, or were treated within the first half-year after birth [Fine, et al., 2003; Maurer, Ellemberg and Lewis, 2006]. Through Project Prakash, we had the opportunity to study a large number of patients in India who were blind since early in life and treated past the age for normal development of contrast sensitivity. Patients were tested in two sessions separated by six months; the first test session was conducted one week to 2 years after treatment. The pre-surgery acuity of these patients ranged from light perception to finger counting at a distance of one meter. Patients were tested binocularly on an iPad [Dorr, et al., ECVP 2012]. The test presented band-passed Lea symbols using a Bayesian adaptive method to estimate contrast sensitivity functions [Lesmes, et al., 2010]. Results show that all patients recovered some vision in the lower spatial frequency range, and some patients even showed peak sensitivities (thresholds<1%) that were equivalent to sighted controls, but shifted to lower frequencies. Some patients showed significant improvements after six months, suggesting neural adaptation to the newly acquired visual input, but the extent of improvement was highly variable across patients. The age, level of pre-operative vision (light perception vs. finger counting), and time since treatment did not predict the extent of improvement over time. These results suggest that the human visual system has the capacity to develop contrast sensitivity after long-term deprivation, but it is still unknown which factors influence the extent of recovery.

Acknowledgement: NIH R01EY019281 to Peter Bex and R01EY020517 to Pawan Sinha

24.14, *3:15 pm*

Video Games Training Increases Reading Abilities in Children with Dyslexia

Simone Gori[1,2](simone.gori@unipd.it), Sandro Franceschini[1], Milena Ruffino[2], Simona Viola[1], 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 the children: they are affected by a neurodevelopmental disorder called dyslexia. In these children reading is slow and error prone, producing serious cascading influences on their life. Reading acquisition is a difficult challenge for the integration of auditory-phonological and visual-orthographic systems. The causes of dyslexia are still debated. An auditory-phonological processing disorder and a visual-attentional impairment seem to be the core deficits of dyslexia. However, dyslexia remediation is far to be fully obtained and the current treatments are highly resources-demanding. Here we demonstrate that only 12 hours playing action videogames – not involving any direct phonological or orthographic training – drastically improve the reading abilities of children with dyslexia. We tested reading, phonological, and attentional skills in two carefully matched dyslexics groups (N=20), before and after playing action or non-action videogames, for 9 sessions of 80 minutes per day. We found that only the group playing action videogames improved their reading abilities, superior to 8760 hours of spontaneous reading development. Attentional skills also improved during the videogames training. Individual differences in visual spatial and cross-modal temporal attention improvements accounted for about 50% of unique variance in the reading enhancement after controlling for age, IQ and phonological skill change. It has been demonstrated that only action videogames improved attention abilities, our results showed how this attention improvement can directly translate in better reading abilities providing a new, fast and fun remediation of dyslexia that also has theoretical relevance in unveiling the causal role of attention for reading acquisition.

See page 3 for Abstract Numbering System

Saturday PM

24.15, *3:30 pm*

Infants differentially anticipate the goals of ipsilateral and contralateral reaches Alexis Barton[1](aabarton@indiana.edu), Bennett Bertenthal[1]; [1]Indiana University - Psychology

When adults observe their own goal-directed actions or those of others, they anticipate the goal before it is completed. Some researchers hypothesize that the prediction of goal-directed actions is facilitated by the activation of corresponding motor representations. If this hypothesis is correct, then the development of predictive looking toward the goal should covary with the development of the corresponding motor representation. This question is addressed in the current study by comparing the observation of ipsilateral reaches to the later developing contralateral reaches. Forty infants (age 6-12 mo) were tested in a gaze-contingent paradigm. This paradigm is more engaging and rewarding for infants resulting in a greater number of scoreable trials. Infants contributed an average of 48 trials to analysis. Each trial began with an actress drumming her fingers on a table to attract the infant's attention to her hands, and then she reached either ipsilaterally or contralaterally to lift a lid and reveal an animated reinforcer. The infant's gaze was recorded on a Tobii TX 300 eyetracker and classified as a predictive look if the gaze of the infant arrived at the AOI associated with the correct lid before the actor's hand. The results revealed that infants made predictive looks on a greater proportion of trials for ipsilateral than contralateral reaches. Infants were also much more likely to incorrectly predict an ipsilateral target location during a contralateral reach than vice versa. Addtitional measures such as earlier fixation latency and longer saccade lengths supported an ipsilateral bias in prediction. These differences were weakly present at 6 months and became more significant through 12 months. This ipsilateral bias suggests that experience with goal directed reach facilitates the prediction of another's reach.

24.16, *3:45 pm*

Infants prefer faces to non-faces but their face processing is not always automatic Mee-Kyoung Kwon[1](mkwon@ucdavis.edu), Mielle Setoodeh[1], Lisa Oakes[1]; [1]Department of Psychology, University of California, Davis

The ability to selectively attend to faces in crowded visual scenes is an important everyday-life skill. Infants younger than 6 months, however, appear to have limited ability to focus on faces. Young infants look equally long at faces and other objects whereas infants older than 6 months more quickly detect faces or maintain attention longer to faces than to other objects (Di Giorgio et al., 2012; Frank et al., 2009). The present study examined how infants' selective attention to faces develops during the first postnatal year and whether young infants' limited ability is due to slow encoding or eye-movements. We recorded infants' eye-movements during a visual search task, determining which item infants fixated first and the total duration that infants fixated each item. In Experiment 1, we presented 4-to 8-month-old infants with 12 displays containing a face and 5 other complex objects for 5 s. Four-month-old infants failed to direct their first fixation to the face, but they looked at the faces for longer durations than expected by chance. Six- and 8-month-old infants both directed their first looks and had total looking durations to faces more than expected by chance. Experiment 2 showed that 4-month-old infants had longer durations, but not increased numbers of first fixations, to faces when trial duration was increased to 12 s. Experiment 3 provides evidence that 4-month-olds' failure to direct their first fixation to faces is not due to slow eye-movements. When presented with arrays of simple objects (e.g. 1 red circle and 5 green circles) 4-month-old infants' first looks and look durations to the salient object (e.g. red circle) were different from chance. These results suggest that although faces are attractive to infants, there are substantial developmental changes in infants' face processing in complex visual displays between 4 and 6 months.

Acknowledgement: This research was supported by NIH grants R01EY022525

24.17, *4:00 pm*

Heterogeneity in cognitive maturation and aging: Why there is no such thing as an adult control Laura Germine[1,2,3](lgermine@fas.harvard.edu), Joshua Hartshorne[4], Jeremy Wilmer[5], Christopher Chabris[6], Garga Chatterjee[4], Ken Nakayama[1]; [1]Psychology Department, Harvard University, [2]Psychiatry Department, Massachusetts General Hospital, [3]Center for Human Genetic Research, Massachusetts General Hospital, [4]Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, [5]Psychology Department, Wellesley College, [6]Department of Psychology, Union College

Research on cognitive change typically focuses on early development or aging, and thus we have little knowledge of cognitive changes that might occur in adulthood. Taking advantage of large Web-based samples, we previously showed that both face learning ability and approximate number sense peak relatively late in adulthood (after age 30), whereas recognition memory for inverted faces and memory for names peak much earlier (Germine et al., 2011; Halberda et al., 2012). Here, we expand on these findings by examining cognitive change over the lifespan across a wide range of cognitive abilities. First, we present results from a systematic analysis of published data from the Wechsler Adult Intelligence Scales and Wechsler Memory Scales showing that there is wide variation in the ages of peak performance on standardized IQ and memory tests. Second, we present findings from year-by-year analysis of large web samples on tests of processing speed, verbal and visual recognition memory, verbal and visual working memory, complex emotion perception, and crystallized verbal intelligence (sample sizes ranging from 3,000 to 10,000 for each test). Again, we find substantial heterogeneity in the peaks of different cognitive functions across the age range. While some cognitive abilities peak very early, declining after age 20 (e.g. processing speed), other cognitive abilities do not peak until around age 40 (e.g. complex emotion perception). Our findings also add to the growing list of cognitive functions that peak around age 30, including verbal and visual domains of working memory. Our data support the notion that changes in cognitive function over the lifespan are impacted by age-related change in multiple, dissociable factors. Finally, our data suggest that there is no age at which an adult has reached peak for all major cognitive functions.

Attention: Neural mechanisms and models

Saturday, May 11, 2:30 - 4:15 pm

Talk Session, Royal Ballroom 4-5

Moderator: Lorella Batelli

24.21, *2:30 pm*

Sensory Processing with Varying Degrees of Attention: Lessons from Hemispatial Neglect Sarah Shomstein[1](shom@gwu.edu), Fatma Uyar[1], Adam Greenberg[2], Marlene Behrmann[2]; [1]George Washington University, [2]Carnegie Mellon University

Following right parietal lobe damage, patients with hemispatial neglect display impairments in attending to information on the left side of space. Recent theories suggest that this spatial attention deficit arises from structural/functional perturbation of the balance between the dorsal and ventral attentional networks. The consequence of the attentional imbalance on the sensory signals elicited in response to visual stimulation is not yet understood. Neglect offers a unique opportunity to examine direct consequences of attention on sensory processing by measuring behavioral and neural responses to a stimulus presented in the unaffected right side of space as compared to the same stimulus presented to the affected left side of space. Here, we compared neural signals elicited in response to the attended and neglected visual stimulation in patients with right parietal lobe lesions and intact occipital and temporal cortex. FMRI was used to localize four visual field locations in sensory regions V1-V4, FFA, and PPA. In addition, patients performed a fixation task while task-irrelevant images of faces and houses were presented in 4 locations. Univariate analysis showed greater difference between the preferred and non-preferred stimuli as one moves anteriorly from V1, V2, V3, V4, to PPA, and FFA, in left versus right hemisphere. The reduction of right hemisphere response to preferred stimuli was correlated with the severity of neglect. The signal integrity within the two hemispheres was tested separately with multivariate analysis. Category and location information in right hemisphere ROIs was lower as compared to the left hemisphere as evidenced by lower within-category cross correlation coefficients and classification accuracies. These results provide evidence that attention directly affects perceptual processing by improving the integrity of sensory responses elicited in visual cortex via magnifying the difference between the response to preferred and non-preferred stimuli.

Acknowledgement: R21-EY021644

24.22, *2:45 pm*

Stimulation of the left parietal lobe improves spatial and temporal attention in right parietal lobe patients: tipping the inter-hemispheric balance with TMS Sara Agosta[1](sara.agosta@iit.it), Florian Herpich[1], Francesco Ferraro[2], Gabriele Miceli[3], Sarah Tyler[5], Emily Grossman[5], Lorella Battelli[1,4]; [1]Center for Neuroscience and Cognitive Systems, Italian Institute of Technology, Rovereto, Italy, [2]Azienda Ospedaliera Carlo Poma, Mantova, Italy, [3]Neurocognitive Rehabilitation Center, CeRiN, University of Trento, Rovereto, Italy, [4]Berenson-Allen Center for Noninvasive Brain Stimulation and Department of

Neurology, Beth Israel Deaconess Medical Center, Harvard Medical School, [5]Visual Perception and Neuroimaging Lab, Department of Cognitive Sciences University of California Irvine, Irvine

It is widely accepted that the right parietal lobe has an advantage over the left in visual attentional tasks. However, such asymmetry is poorly understood. For example, while patients affected by right parietal lesion show severe deficits in attentional tasks in the contralesional space, other studies have demonstrated that the deficits can be equally severe in the ipsilesional space (Battelli et al., 2007). fMRI studies on patients have shown that areas in the healthy hemisphere are hyperactive along with attentional deficits in the contralesional field. One hypothesis is that these deficits are a consequence of an increased inhibition exerted on the damaged hemisphere by the hyperactive unaffected hemisphere (Kinsbourne, 1977). Here we used TMS on the healthy hemisphere in right parietal patients to tip the balance between hemispheres to relieve patients' symptoms in spatial and temporal attention tasks. Patients completed a I) a multiple object tracking task, in which they were asked to track 2 or 4 moving discs amidst moving distracters (8 total discs, four in each hemifield) in the left and/or right hemifield and, II) a simultaneity judgment task in which they were asked to judge whether two of four flickering disks (two in each hemifield) were in or out-of-phase. For each task patients underwent two counterbalanced sessions: 1Hz TMS over the left (healthy) parietal lobe and sham control stimulation. Their performance was compared before and after stimulation. At baseline patients were impaired in the contralesional field on multiple objects tracking while they showed a bilateral deficit in the simultaneity task. However, after 10min-TMS patients' performance selectively improved on the side contralateral to the lesion in both tasks. The results show that TMS might have beneficial effects on rehabilitation of spatial and temporal attention deficits by re-balancing the activity of the two parietal lobes.

24.23, *3:00 pm*

Mechanisms of attentional control in fronto-parietal cortex across spatial positions

Miranda Scolari[1,2](mscolari@princeton.edu), Sabine Kastner[1,2]; [1]Department of Psychology, Princeton University, [2]Princeton Neuroscience Institute, Princeton University

An abundant and varied set of studies has established that attention can be directed to a particular region of space, such that visual input at an attended location is preferentially processed over input at unattended locations (space-based attention or SBA), and this processing bias is manifested in visual cortex. More recently, it has been explored how SBA modulation of sensory signals is controlled via higher-order cortical networks. Based on early patient observations that have since been refined by contemporary imaging studies, topographic subunits within fronto-parietal cortex have been implicated as a source of control. This control network is best described as a gradient of attention across space, wherein the two hemispheres operate in concert by generating attentional weights in favor of the contralateral visual field (interhemispheric competition account). When a relevant item appears in one visual field, the weighting sum is biased in the corresponding direction. We hypothesized that the magnitude of the spatial bias should dictate not only the attended hemifield, but also the eccentricity at which attention is focused. Using high-resolution fMRI, we estimated interhemispheric competition (via a contralateral bias index) for each topographic subunit of fronto-parietal cortex to determine how the control network signals fluctuations in stimulus position. Subjects either attended to a single flickering grating appearing at one of four eccentricities from fixation (2°, 5°, 8°, or 12°), or to an RSVP letter stream at fixation. As expected, SBA effects were observed in all visual (V3v-V7), parietal (IPS0-5, SPL1) and frontal (FEF, PreCC) areas. The contralateral bias showed no systematic patterns across eccentricities in visual or frontal cortex. However, the bias tended to increase with eccentricity in parietal regions. This is consistent with previous hypotheses that frontal cortex is primarily involved in general, goal-directed components of attention, whereas parietal cortex is primarily involved in stimulus-driven components.

24.24, *3:15 pm*

Firing synchrony between neurons reveals proto-object representation in monkey visual cortex

Anne Martin[1](annebmartin@gmail.com), Rudiger von der Heydt[1,2]; [1]Department of Neuroscience, College of Medecine, The Johns Hopkins University, [2]The Zanvyl Krieger Mind/Brain Institute, The Johns Hopkins University

An unresolved question in neuroscience is how the brain represents objects. Theories have proposed that synchrony of firing might encode how features relate to objects (feature binding theory1,2), or highlight information for selective processing (attention coding theory3), but the underlying mechanisms are largely unknown. One hypothesis is that synchrony in visual cortex is produced by shared feedback from 'grouping cells' that specifically enhance the activity of neurons whose receptive fields fit their grouping templates. This mechanism is thought to instantiate proto-objects, providing a structure for selective attention4,5. Here we show that spike time correlations between neurons in monkey visual cortex (V1, V2) reveal the workings of this mechanism. We used border ownership selectivity6 to infer how neurons are linked in proto-object structures (POS). We found that synchrony depends on whether two neurons are part of the same POS. Synchrony was three times higher in same-POS pairs than in different-POS pairs. Synchrony in same-POS pairs increased when they were stimulated by contour segments of the same object (binding) compared to segments of different objects, whereas in other pairs it did not change. In same-POS pairs, synchrony decreased with attention, in the others it increased. These results confirm the existence of specific feedback circuits that define proto-objects. While previous theories have linked synchrony in visual cortex to stimulus configuration and mode of attention, our results show that the key to understanding synchrony is the place of the neurons in the proto-object representation. References: 1. von der Malsburg,C. In Brain Theory. Proceedings of the First Trieste Meeting on Brain Theory, 1984. 2. Gray,C.M., et al. Nature (1989). 3. Niebur,E., et al. Vision Res. (1993). 4. Craft,E., et al. J. Neurophysiol. (2007). 5. Mihalas,S., et al. PNAS (2011). 6. Zhou,H., et al. Journal of Neuroscience (2000).

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24.25, *3:30 pm*

Effects of perceptual load on population receptive fields

Benjamin de Haas[1, 2](benjamindehaas@gmail.com), D. Samuel Schwarzkopf[1,2], Elaine J. Anderson[1,2,3], Geraint Rees[1,2]; [1]Institute of Cognitive Neuroscience, University College London, [2]Wellcome Trust Centre for Neuroimaging, University College London, [3]Institute of Ophthalmology, University College London

Perceptual load at fixation reduces detection performance for peripheral stimuli and the neural responses they evoke. Here we used functional MRI and population receptive field (pRF) mapping (Dumoulin, 2008, NeuroImage, 39(2), 647-60) to test whether foveal load changes the spatial tuning functions of voxels in human V1-3. Participants (n=28) performed a fixation task at the centre of the screen (Schwartz, 2005, Cereb Cortex, 15(6), 770-786) while dynamic, high-contrast bar stimuli traversed the visual field. Each participant completed 4-8 mapping scan runs. High and low load fixation tasks alternated between runs (n=14) or once per run (n=14). Additionally, each participant completed two scan runs to estimate their individual hemodynamic response function (HRF) under either condition. We used the resulting HRF estimates for high and low perceptual load to generate predictions for the time series of respective mapping runs. Predictions were based on the assumption of two-dimensional Gaussian pRFs. We estimated pRF centre position and size according to the best fit between predictions and actual data. High perceptual load at fixation increased pRF sizes in para-foveal V1-3 (~3-6 degrees eccentricity). Additionally, the eccentricity of foveal pRFs in V1-3 (up to ~1 degree eccentricity) was pulled outwards. Thus, high attentional demand at central fixation yielded a blurring effect on representations outside the central visual field and a centrifugal effect for the representation of mapping stimuli very close to the task stimuli. These effects may reflect the competition between the representation of central target and task-irrelevant mapping stimuli. They indicate that attention changes the spatial tuning properties of pRFs. This could be a physiological mechanism for early attentional selection under high perceptual load, as suggested by Lavie's load theory (Lavie, 2005, TiCS, 9(2), 75-82).

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24.26, *3:45 pm*

Pupil Frequency Tagging: an on-line measure of visual attention

Marnix Naber[1](marnixnaber@gmail.com), George Alvarez[1], Ken Nakayama[1]; [1]Vision Sciences Laboratory, Department of Psychology, Harvard University

The muscles that control the pupil are richly innervated by the autonomic nervous system. While there are central pathways which modulate pupil size in relation to arousal, there is no anatomical evidence that centers involved with higher order cognition innervate the pupil. In this study, we show that such connections must exist and that they reflect the operation of visual selective attention. In our first study observers gazed at a fixation point while they attended one of four separate objects. Each object had a distinct location and flicker frequency (1.50, 1.75, 2.00, and 2.25Hz). Results showed that the frequency of the attended object was selectively enhanced in the pupil response dynamics. In the second experiment, our aim was to show that we could predict behavioral performance from the frequency tagged response. Here we had subjects centrally fixate while

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tracking a slowly moving flickering disk (2Hz). A stream of changing letters was superimposed on the disk and observers were instructed to hit a button whenever the target letter "x" was shown. Improved detection of the "x" was correlated with increased amplitude of the pupillary response. These surprising results taken together show that pupil responses closely follow the allocation and strength of focal visual attention. They provide a new opportunity to study visual attention and also invite investigation as to the pathways and mechanisms of this phenomena.

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24.27, *4:00 pm*

Spatial and feature-based attention enhance the Pupillary Light Reflex Paola Binda[1,2](p.binda1@in.cnr.it), Maria Pereverzeva[1], Scott O Murray[1]; [1]University of Washington, Department of Psychology, 98195-1525 Seattle (WA), [2]Universita' di Pisa, Dipartimento Integrato Interistituzionale, via Savi 10, 56126 Pisa (Italy)

Attention optimizes the processing of behaviorally relevant visual information by acting through multiple mechanisms, including neural response enhancement and sharpened tuning. One longstanding question is how early in the visual system attention exerts its influence. Here we investigate the effects of attention at the earliest possible level, the pupil of the eye. The diameter of the pupil modulates the amount of retinal illumination and the optical quality of the visual image, affecting visual acuity and sensitivity. The pupil constricts in response to light increments, mainly under the control of a subcortical reflex pathway; this ensures that the pupil diameter remains optimal across a wide range of illumination conditions. Our experiments show that attending to a bright surface results in a pupil constriction. On each trial, we presented a bright and a dark surface, either at separate peripheral locations (a bright and a dark disk to the left and right of fixation) or at the same central location (overlapping fields of bright and dark dots, rotating in opposite directions). Subjects were cued to attend to one surface and detect threshold-level events, while ignoring the other surface. Though retinal stimulation was the same across trials, a relative pupil constriction was observed when attention was directed to the bright surface. The effect was the same, irrespective of whether the attended surface was selected based on its spatial location or its features. Control experiments showed that attention selectively modulates the pupillary constriction evoked by light increments, leaving unaffected the pupillary dilation in response to light decrements. Our results reveal a new mechanism through which attention optimizes visual processing, by acting at the point where information enters the visual system to modulate the pupillary light response.

Acknowledgement: EC FP7 Marie Curie IOF fellowship to PB University of Washington RRF to SOM

Color and light: Mechanisms

Saturday, May 11, 5:15 - 6:45 pm

Talk Session, Royal Ballroom 1-3

Moderator: Andrew Stockman

25.11, *5:15 pm*

The Four Human Visual Mechanisms Sensitive to Gray Scale Scrambles Charles Chubb[1](cfchubb@uci.edu), Andrew E. Silva[2]; [1]Department of Cognitive Sciences, University of California at Irvine, [2]Department of Psychology, University of California at Los Angeles

Previous research has shown that human vision has three dimensions of sensitivity to grayscale scrambles (spatially random mixtures of different grayscales). However, the mechanisms that confer this sensitivity remain obscure. The current experiments resolve this issue by focusing on search asymmetries revealed when the participant is required to localize a small, circular target patch of scramble with one histogram in a large annular background of scramble with a different histogram. For each of three orthogonal histogram perturbations λk, k=1,2,3, the participant was tested in two (separately blocked) complementary attention conditions: in the first attention condition, the target histogram was dominated by λk and the background was dominated by $-\lambda k$; in the second, the target histogram was dominated by $-\lambda k$, the background by λk. Results are modeled by assuming that (1) the participant has a fixed set of mechanisms, each of which is activated nonnegatively by different grayscales, and (2) in a given attention condition the participant uses an optimal linear combination (with weights constrained to sum to 1) of only those mechanisms more strongly activated by the target than by the background. Each of three participants yields the same pattern of results. Four mechanisms are implicated: (1) one mechanism whose sensitivity is zero for black, increases linearly with increasing grayscale and saturates near white; (2) another mechanism whose sensitivity is maximal for black, decreases linearly and flattens to 0 near white; (3) the (previously characterized) "blackshot" mechanism, sharply tuned to the blackest grayscales; (4) a (previously unknown) mechanism whose sensitivity is zero for black, rises sharply to its maximum for grayscales slightly darker than mid-gray, then falls to uniform half-height for all higher grayscales. Because the sensitivity functions of mechanisms (1) and (2) are nearly linearly dependent, these mechanisms collectively confer sensitivity to a 3-dimensional space of histogram variations.

Acknowledgement: NSF Award BCS-0843897

25.12, *5:30 pm*

The anisotropy of color space Marina Danilova[1,2](mar.danilova@gmail.com), John Mollon[2]; [1]Laboratory of Visual Physiology, I.P.Pavlov Institute of Physiology, St. Petersburg, Russia, [2]Department of Experimental Psychology, Cambridge University, Cambridge, UK

Color discrimination is conventionally thought to depend on two neural signals. One signal, carried by midget ganglion cells, represents the ratio of the long- (L) and middle-wave (M) cone excitations. This signal corresponds to the horizontal axis of the MacLeod-Boynton chromaticity diagram. The second signal, carried by small bistratified ganglion cells, represents the ratio of short-wave (S) cone excitation to some combination of L and M excitations, and corresponds to the vertical axis of the MacLeod-Boynton diagram. Phenomenologically, however, the MacLeod-Boynton space is not symmetrical about a vertical line through the white point: It is divided into reddish and greenish hues by a line that runs obliquely, from unique yellow to unique blue. We scale the MacLeod-Boynton diagram so that the yellow-blue line lies at an angle of -45° (Danilova & Mollon, 2012, Vision Research, 62, 162-172). Measuring discrimination along lines orthogonal to the yellow-blue line (i.e. lines at +45° in the space), we previously found that forced-choice thresholds were minimal at the category boundary between reddish and greenish hues – and not, say, at a constant value of L/M or of S/(L+M). However, what would happen if we reflect our experiment about the vertical axis of MacLeod-Boynton space, measuring chromatic discriminations along lines that are at -45°? We measured such discriminations for 150-ms, foveal targets divided into four quadrants, requiring observers to report the quadrant that differed in chromaticity from the other three. Observers were adapted to a field metameric to Illuminant D65. Two main results emerge: (i) discrimination along -45° lines does show a shallow minimum and (ii) for lines not passing through D65, the minimum does not coincide with the L/M value of the background. We conclude that a phenomenological boundary is not necessary for a minimum in discrimination measurements.

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25.13, *5:45 pm*

Geometrical structure of perceptual color space is affine Robert Ennis[1](rennis250@gmail.com), Qasim Zaidi[1]; [1]Graduate Center for Vision Research, SUNY Optometry

Color spaces (e.g., CIE, Macleod-Boynton, and CIELUV) are invaluable for specifying colors. However, CIE and M-B space only predict which spectral distributions will match, while CIELUV deals with the discrimination of small color differences. There is much more to color perception than matching and discrimination. For example, similarities between colors (Zaidi & Bostic, 2008) and between color changes (Zaidi, 1998) can be used to identify materials across illuminants. Uniform color spaces based on multi-dimensional scaling of similarity ratings do exist, but these rely on Euclidean assumptions shown to be untenable (Wuerger, et al, 1995). We investigated the geometrical structure underlying relative similarity judgments. In a metric space, the distance between chromaticities would represent their magnitude of similarity, but even in a weaker affine space, ratios of distances between colors on a line would provide measures of relative similarity, and parallelism would define similarity between color changes. We tested whether affine geometry holds for a mid-point setting task. We chose two large quadrilaterals in the M-B equiluminant color plane. On each trial, observers viewed three colored patches, two of which were the endpoint colors forming one side of the quadrilateral. Observers were instructed to consider the color change between the test patches in terms of "reddish-greenish" and "bluish-yellowish" components and to set the color of the middle patch, by adjusting its hue and saturation, to the combined midpoint of the change on the two dimensions. After finding the mid-point for the four sides, observers set the midpoints between the two pairs of facing mid-points. For four observers, the two final mid-

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points for each quadrilateral coincided, thus satisfying Varignon's Theorem and passing the affine test. A perceptual color space based on relative similarities across large color differences thus has an affine structure.

Acknowledgement: Grants: EY007556, EY013312

25.14, *6:00 pm*

Highly-selective chromatic masking does not require large numbers of color mechanisms Rhea T. Eskew, Jr.[1](eskew@neu.edu), Timothy G. Shepard[1]; [1]Psychology, College of Science, Northeastern University

A central issue in color vision is the nature and number of mechanisms that process signals from the cones. Some groups, including ours, have selected stimuli and analyzed data represented in cone contrast space, and found results consistent with a limited set (e.g., 6) of (unipolar) mechanisms. Other groups, working in cone excitation space, have found evidence for a larger number of ("higher order") mechanisms. Hansen and Gegenfurtner (2010 VSS) argue that this empirical discrepancy is due to a poor choice of color angles by researchers using cone contrast space. When they used chromatic masking noise with a color angle near the corner of the detection contour in the ($\Delta L/L$, $\Delta M/M$) plane of cone contrast space, Hansen and Gegenfurtner found masking that was highly selective for that noise color direction. Their interpretation was that there are multiple color mechanisms, including some tuned to color directions near the noise direction. We have replicated Hansen and Gegenfurtner's result, using randomly flickering colored lines (42°/222° and 48°/228° in the ($\Delta L/L$, $\Delta M/M$) plane) superimposed on 1 cpd Gabor tests. As they reported, masking was highly selective, with thresholds elevated most at the noise angle, even compared to angles only 3° away. However, we show here that selective masking can occur with no more than six linear color mechanisms when the mechanisms are not orthogonal. It is not necessary to postulate multiple mechanisms, and certainly not necessary to have mechanisms tuned to the noise direction, to account for selective masking: even very simple models can generate this apparently-complex behavior. Whether the simplest of these models can account for all the published results on chromatic detection is an open question, but a selective masking result alone is not sufficient to reject models with a limited number of mechanisms.

25.15, *6:15 pm*

Multiple S-cone signals inferred from flicker measurements suggest a network of indirect connections into luminance Andrew Stockman[1](a.stockman@ucl.ac.uk), G. Bruce Henning[1], Caterina Ripamonti[1]; [1]Deptartment of Visual Neuroscience, UCL Institute of Ophthalmology

The properties of S-cone flicker measured on longer-wavelength backgrounds are consistent with S-cone signals' being transmitted by an achromatic pathway shared with L- and M-cone signals. One unusual property of this S-cone signal, which suggests that it is not a direct input, is that it is inverted in sign and delayed. We have looked in detail at S-cone temporal-frequency responses in normal observers and clinical observers with altered S-cone function. We confirm the findings of Wisowaty & Boynton [1980, Vision Research, 20, 895] that the S-cone responses with and without long-wavelength adaptation are different. On long-wavelength backgrounds, the data suggest the existence of multiple S-cone signals. We model the results by supposing that the S-cones interact with L- and M-cones via a network of indirect lateral connections, and that each step in the network inverts and delays the S-cone signal. If the S-cone interaction is via one step, the signal is delayed and inverted, if it is via two steps it is doubly-delayed but "uninverted", and so on. The converging S-cone signals destructively or constructively interfere at different frequencies to produce characteristic patterns in the S-cone temporal frequency response. Our results further suggest that the relative strengths of 1-step, 2-step and 3-step S-cone signals vary between observers (presumably because of variability in the underlying S-cone photoreceptor density) to produce distinctive individual differences in the shapes of the S-cone temporal-frequency response. Our model is bolstered by measurements in observers with altered S-cone function, including an S-cone monochromat with only S-cones, enhanced-S-cone-syndrome patients with an excess of S-cones, and a CSNB patient without ON-pathways. The 1-, 2- and 3-step model makes specific predictions for each type of observer. We speculate that the network is provided by horizontal cells that feed back through L- and M-cones in single or multiple steps.

Acknowledgement: BBSRC

25.16, *6:30 pm*

Adaptation to twinkle and flicker Stuart Anstis[1](sanstis@ucsd.edu), Alan Ho[2], Neal Dykmans[1]; [1]Dept of Psychology, UC San Diego, [2]Dept of Psychology, Ambrose University College, Calgary, Alberta

We find that adaptation to twinkle or flicker slows down the perceived rate of twinkle, flicker, and motion. Twinkle adaptation. Observers adapted to a field, 11° wide x 22° high, of twinkling dynamic random noise, namely black/white random dots (6 minarc diam) that refreshed with spatially uncorrelated dots 27 times per second. They then viewed random test dots that twinkled at rates between 8 and 27 fps on different trials. Result: a matching method showed that the test dots now appeared to twinkle at half their actual rate. Observers also adapted to a random-dot pattern that flickered in counterphase, alternating between its own positive and negative 27 times per sec (13.5 Hz). After this adaptation, a fresh field of test dots that counterphased at 4 to 13.5 Hz appeared to flicker at about half its actual rate. We attribute these results to visual filters tuned to different temporal frequencies, with spatial resolution able to resolve the fine-grain random dots. Flicker adaptation. Following adaptation to a spatially uniform rectangle that flickered between black and white at 13.5 Hz, a congruent uniform test rectangle flickering at 4 to 13.5 Hz appeared to fall to 70% of its actual flicker rate. We attribute these results also to temporally tuned visual filters, but of undetermined spatial resolution. Cross-adaptation. Adapting to 27 fps twinkle caused test random dots that drifted at speeds between 0.25°/s and 3°/s to slow down perceptually to 60--80% of their actual speed. Possibly, twinkle contains apparent movement in all directions that adapt all motion sensors. Similarly, adapting to 13.5Hz spatially uniform flicker also reduced perceived test speeds to 80% of their actual speed. This implies that prolonged viewing of flicker leads to adaptation of the temporal, not spatial, components of the test motion.

Acknowledgement: UCSD Dept of Psychology

Visual search: Guidance, efficiency

Saturday, May 11, 5:15 - 6:45 pm

Talk Session, Royal Ballroom 4-5

Moderator: Preeti Verghese

25.21, *5:15 pm*

Welcome to Vowelworld: A new approach to the guidance of search in scenes. Jeremy M Wolfe[1,2](wolfe@search.bwh.harvard.edu), Amanda (Min Hui) Choo[3]; [1]Brigham and Women's Hospital, [2]Harvard Medical School, [3]Raffles Institution, Singapore

Consider search for big yellow grapefruits in the supermarket. Search for these targets will be guided by features of the target. Size, shape and color features will guide attention to round, yellow items. In addition, at least three scene-based properties guide search. 1) Scene Gist - The produce section is a good place to search for grapefruits; the meat counter is not. 2) Scene syntax – Grapefruits obey physical constraints like gravity and must be placed in displays where they will not fall or roll. 3) Scene semantics – Grapefruits are more likely to occur near lemons and oranges and not near cabbage and lettuce, even though both locations are physically possible. Scene guidance is hard to control parametrically using real scenes. Vowelworld is an artificial world that permits control of versions of scene guidance rules. Observers search for vowels in arrays of consonants on multicolored, checkered backgrounds. Background colors provide "gist guidance." A's are more likely to be in red regions; "I" in blue, etc. Chains of circles provide "syntactic guidance." Vowels can be constrained to lie on or next to circles. Letter gradients provide "semantic guidance." Vowels lie near their neighbors in the alphabet. U's would be near S, T, & Vs. Observers searched for vowels with no rules, one rule, or all rules active in arrays of 100, 200, 300 or 400 letters. Errors and RTs fell as rules were added, with performance significantly better with all rules on than with all rules off. Each guiding cue contributes to search efficiency and a combination of all three rules appears more effective than simple multiplicative combination of individual contributions. Cue validity can be varied. For example, with 0.9 valid color cues, invalid colors produce higher errors (37vs14%) and RTs (9200vs7300msec). Similar results are obtained with other cues.

Acknowledgement: ONR:N000141010278, NIH:EY017001

25.22, *5:30 pm*

Visual Expertise: Insights Gained by Comparing Professional Populations Kait Clark[1](kait.clark@duke.edu), Adam T. Biggs[1], Elise F. Darling[1], Matthew S. Cain[2], Tate H. Jackson[3], Ehsan Samei[4], Jay A. Baker[4], Stephen R. Mitroff[1,3]; [1]Duke University, Center for Cognitive Neuroscience, Department of Psychology & Neuroscience, [2]Brown University, Department of Cognitive, Linguistic, & Psychological Sciences, [3]University of North Carolina at Chapel Hill, Department of Orthodontics, [4]Duke University Medical Center, Department of Radiology

Professionals whose careers depend on visual skills typically demonstrate superior performance on career-related tasks; farmers better determine the sex of day-old chicks (Biederman & Shiffrar, 1987), and bank tellers better detect counterfeit currency (Klein, Gadbois, & Christie, 2004). Perceptual expertise has implications for learning and malleability, but the interpretation of expertise benefits is not straightforward. Complications arise, in part, because standard methodologies typically compare professionals to laypersons, raising concerns about confounding differences (e.g., motivation, speed/accuracy tradeoff, self-selection). Additionally, the mechanisms responsible for improvement may be ambiguous (e.g., enhanced sensory discrimination vs. improved strategies). To account for these issues, we analyzed performance across different professional groups on tasks related and unrelated to their careers. We assessed two groups of visual search experts (radiologists, airport security screeners), one group of facial symmetry experts (orthodontists), and one non-professional group (university participants). As expected, the professional groups demonstrated superior accuracy for career-related tasks (radiologists and airport security screeners for search, orthodontists for facial symmetry), and additional comparisons provided further insight. To evaluate potential differences in motivation, we compared performance on a task unrelated to the professionals' expertise—temporal order judgment—and found no accuracy differences between professionals and non-professionals. Relatedly, comparisons between professional groups minimized speed/accuracy tradeoff concerns; professionals were slower on all tasks but only showed enhanced accuracy for career-relevant tasks. To elucidate whether benefits arose from self-selection or experience, we compared early- versus late-career individuals within the same profession and found differences related to amount of experience. Finally, we explored the nature of experts' improvements and found evidence supporting superior top-down strategy selection (search professionals choose more effective strategies) as well as bottom-up stimulus-specific processing (orthodontists revealed enhanced symmetry discrimination for faces only). By comparing different types of experts on multiple tasks, we can better inform the nature of visual expertise.

Acknowledgement: Army Research Office (SRM), Dept. Homeland Security (SRM)

25.23, *5:45 pm*

Effects of Bottom-Up Versus Top-Down Cueing on Conjunction Search in 3-Month-Old Infants

Christina Fuda[1, 2](cfuda@yorku.ca), Scott Adler[1, 2]; [1]Centre for Vision Research, [2]York University

Previous research with infants has indicated that they are fully capable of performing a feature search in a manner nearly identical to adults (Adler & Orprecio, 2006; Fuda & Adler, 2012), but are developmentally immature in localizing a target in a conjunction search (Fuda & Adler, 2012). This might be accounted for by feature searches relying mainly on bottom-up attentional resources to localize a target, whereas conjunction searches would require top-down attentional resources in addition to bottom-up resources (Wolfe, 1994). Since infants have been shown to perform a feature search but not a conjunction search in a similar manner to that performed by adults, the current study attempted to investigate whether this might be due to bottom-up attentional mechanisms developing before top-down mechanisms. To this end, 3-month-old infants were presented with two types of cues prior to a conjunction search array that provided them with either bottom-up or top-down information that might facilitate their conjunction search. The bottom-up cue consisted of four rectangular frames indicating where the possible location of the target would be, whereas the top-down cue consisted of the brief presentation in the visual center of what the target would be. Infants' saccade latencies were recorded for three different set sizes of (5, 8, & 10) when the target was either present or absent. Results revealed that the top-down cue, but not the bottom-up cue, facilitated infants' exhibition of a more adult-like conjunction search function where latencies increased with increasing set sizes. These findings suggest young infants' top-down processing mechanisms are developmentally immature relative to their bottom-up mechanisms, at least in visual search tasks. Furthermore, this study represents the first time these attentional mechanisms have been assessed in infancy and may serve as a window into understanding not only typical attentional development but also atypical development with attentional deficits.

Acknowledgement: National Institute for Mental Health grant R03-MH085994-01A1 to S.A. Adler

25.24, *6:00 pm*

Immediate feedback improves saccadic efficiency

Preeti Verghese[1](preeti@ski.org), Saeideh Ghahghaei[1]; [1]Smith-Kettlewell Eye Research Institute, San Francisco

When the task is to find multiple targets in a limited time, saccades need to be efficient to maximize the information gained. In theory, selecting uncertain locations is much more informative than selecting locations most likely to have the target. Contrary to this prediction, previous work has shown that observers fixated likely target locations while searching for multiple targets in noise. Saccade efficiency did not improve despite extensive training with full feedback at the end of each trial (Verghese, 2012). Here we examined whether immediate feedback following each saccade improved saccade strategy. Observers actively searched a display with six disks equally spaced around a 3° eccentric circle. Each location had an independent probability of a signal, so the number of signal disks in a trial ranged from 0 to 6. The luminance of each disk was drawn randomly from Gaussian distributions of signal and noise, with mean separation and standard deviation 5 and 3.33 cd/m2, respectively. Due to the overlap of the distributions, it was uncertain whether a luminance value in the overlap zone came from signal or noise distribution. As an incentive to explore uncertain locations, a saccade to a disk with luminance in the overlap zone generated immediate feedback by switching the disk luminance to the mean value of the "true" distribution. At the end of the 1150 ms display, observers selected all potential signal locations with a cursor. We performed a trial-by-trial analysis of observers' saccades to determine saccade strategy. Initially all observers (n=4) made saccades to likely locations, as in the previous study using delayed feedback. However modest practice with immediate feedback resulted in significant changes to saccade strategy. Observers made more efficient saccades, selecting uncertain locations over likely locations. These findings indicate that immediate feedback is very effective in increasing the efficiency of eye movements.

Acknowledgement: R01 EY022394

25.25, *6:15 pm*

Multimodal neuroimaging evidence for the contribution of the medial temporal lobe to modulations of electrophysiological indices of attention during contextual cueing

Ryan W Kasper[1,2](kasper@psych.ucsb.edu), Scott T Grafton[1,2], Miguel P Eckstein[1,2], Barry Giesbrecht[1,2]; [1]Psychological & Brain Sciences, UC Santa Barbara, [2]Institute for Collaborative Biotechnologies, UC Santa Barbara

Contextual cueing is a facilitation of visual search performance that can result from the repetition of target and distractor spatial configurations (Chun & Jiang, 1998). Neuropsychological and fMRI studies have implicated the medial temporal lobe memory system (Giesbrecht et al, 2012; Greene et al, 2007; Manelis & Reder, 2012) while electrophysiological studies have implicated visual attention systems by showing that the N2pc ERP component is modulated by context (Johnson et al, 2007). However, based on this evidence alone, it remains unclear to what extent these patterns of hemodynamic and electrophysiological neural responses are linked. To investigate this issue, twelve subjects performed a visual search task (256 trials, 50% repeated configurations) in two sessions that were separated by one week. In the first session, 64-channel EEG and whole-brain fMRI data were acquired simultaneously. In the second session, 64-channel EEG was recorded in isolation. Analysis of the behavior indicated a robust RT enhancement for repeated contexts in both sessions ($p < 0.03$). The neuroimaging data were analyzed by first identifying regions of frontal, occipital, parietal, and MTL cortex showing a significant BOLD response to the search task, and then using the locations of those activations to constrain the position of dipoles in an EEG source analysis of the difference between the N2pc ERP component evoked by repeated and novel contexts. The explanatory power of each source was quantified by calculating the change in explained variance when each source was removed from the analysis. This analysis revealed that relative to a random permutation test, the MTL made the most significant contribution to explaining the variance in N2pc modulations by contextual cueing in both sessions ($p < 0.02$). This finding indicates that the MTL memory system may be a critical mediator in the attentional enhancements observed in contextual cueing.

Acknowledgement: Contract W911NF-09-D-0001 from U.S. Army Research Office

25.26, *6:30 pm*

Investigating low-level explanations for the angry schematic-face search advantage

Matthew Kennett[1](matthew.kennett@uqconnect.edu.au), Guy Wallis[1]; [1]School of Human Movement Studies, Health Sciences Faculty, University of Queensland, Australia

The ability to rapidly detect threatening situations would seem to offer an organism an important survival advantage, and hence be something likely to enter its genetic blueprint. History suggests that one major source of threat for humans is another human intending to do harm (either socially or physically); typically evidenced by their facial expression of anger. Thus, an argument has been made that humans have evolved the ability to more rapidly detect angry faces than faces baring other expressions. Initial results in support of this 'anger superiority effect', using pictures of real faces as stimuli, have since been undermined by evidence that the effect is likely due to low-level visual artefacts. In an attempt to control for these artefacts, some researchers have experimented with schematic face images (simple line drawings). Reports have emerged of a strong and consistent search advantage for angry faces. This has been seen as significant because the low-level artefact counter-argument is a much more difficult case to mount. Recently we reported (Coelho, Cloete, and Wallis, 2010) that the search advantage could still be found using images which no longer resembled faces, but maintained similar line structures to the schematics. Nonetheless, by only testing for this effect using a constant set-size, these results could be construed as being due to response biases rather than detection speed per se. This follow-up study specifically addressed this concern by testing over multiple set sizes. The expected variations in search slope were measured for both schematic and abstract line stimuli, confirming that the effect is due to a difference in detection speed. The results confirm therefore, that the search advantage exists, but that it is likely due to low-level visual features rather than a projection of threat. In a follow-up study we describe investigations into the source of this strong search asymmetry.

Saturday Afternoon Posters

Temporal processing

Saturday, May 11, 2:45 - 6:45 pm

Poster Session, Royal Ballroom 6-8

26.301 **The role of time in human decision-making** Marjena Popovic[1](marjenap@brandeis.edu), Mate Lengyel[2], Jozsef Fiser[3]; [1]Graduate Program in Neuroscience, Brandeis University, Waltham, MA, [2]Computational and Biological Learning Lab, Department of Engineering, University of Cambridge, United Kingdom, [3]Department of Cognitive Science, Central European University, Budapest, Hungary

The effects of time on human decision-making are well known, yet, the precise mechanisms underlying these effects remain unclear. Under the classic signal processing framework (e.g. integration-to-bound) the passing of time allows for accumulation of evidence, parametric models of probabilistic neural representations (e.g. PPC) hold that time is used for averaging internal noise for a better estimate of firing rates, while non-parametric, sampling-based models posit that time influences the collection of samples from subjective posterior distributions. These models provide different predictions about the nature and temporal evolution of subjects' errors and the correlation between their error and their subjective uncertainty. We have analytically derived the progression of error and subjective uncertainty in time for the three models under a decision-making scenario, and found characteristic differences in their behavior. Under sampling, after a possible transient decrease depending on the kurtosis of the posterior, the correlation always increases monotonically to an asymptote. Importantly, this increase continues long after the error itself has reached its asymptote. In contrast, both integration-to-bound and PPC models can show increasing or decreasing changes in correlation depending on the posterior's kurtosis, and when noise corrupts the posterior, this correlation decreases. We conducted a decision-making study in which subjects performed time-limited orientation matching and reported their uncertainty about their decisions, and found that the results confirmed both predictions of the sampling-based model. As these characteristics are not present in parametric and integration-to-bound models, the present results lend strong support to a novel use of time in decision-making: collecting samples from otherwise static internally represented distributions.

26.302 **Probing observer metacognition through the analysis of gaze duration estimates** Aurelio Bruno[1](a.bruno@ucl.ac.uk), David Souto[2], Aditi Rao[1], Alan Johnston[1]; [1]Department of Cognitive, Perceptual and Brain Sciences, University College London, 26 Bedford Way, London WC1E 6BT, UK , [2]Faculte ⊠ de Psychologie et des Sciences de l'Education, Universite ⊠ de Geneve, Geneva, Switzerland

Our ability to reliably judge and reproduce time intervals under one or two seconds is surprising, given the variability of the temporal context (Jazayeri & Shadlen, 2010, Nature Neuroscience, 13(8), 1020-1026). This temporal range is particularly important in social interactions that are often managed by gaze duration. In this study, we examined subjects' ability to reproduce the duration of an observed gaze by moving their own eyes. Participants were presented with an avatar reference face that shifted its gaze twice. The interval between the two gaze shifts was the standard duration (500, 1000 or 1500 ms). Subjects had to reproduce this interval by looking at an identical face and then move their eyes away when they thought the same time had passed. At the end of every pair of identical trials, we asked which of the two previous estimates they thought was closer to the standard duration. No feedback was provided. We calculated the mean of the distribution of individual estimates as a measure of perceived duration and the standard deviation of this mean as a measure of observer variability. Although we observed a general underestimation of gaze duration, the mean of the true best estimates did not substantially differ from the mean of the perceived best estimates. However, the standard deviation of the perceived best estimates was lower than that of the perceived worst estimates, indicating subjects had some knowledge of their own performance.

Acknowledgement: The Wellcome Trust

26.303 **How is duration information from multiple sensory sources combined?** Mingbo Cai[1](mcai@cpu.bcm.edu), David Eagleman[1,2]; [1]Department of Neuroscience, Baylor College of Medicine, Houston, [2]Department of Psychiatry, Baylor College of Medicine, Houston

The perception of duration can be biased by the physical properties of a sensory stimulus. For example, visual stimuli with higher temporal frequency are perceived as longer (Kanai et al., 2006). Objects of different temporal frequencies often appear simultaneously in the environment, providing conflicting information about duration. Does the brain keep separate duration representations for each object, or form a single representation? If a single duration representation is kept, how is it formed? One possibility is by Bayesian cue integration (Ahrens & Sahani, 2011); another is by reading out the total neural energy for encoding all the stimuli (Eagleman & Pariyadath 2009, 2012). Human participants estimated the duration of Gabor patterns drifting at 1Hz and 6Hz (denoted by L for low and H for high frequency, and LH when the two were simultaneously presented. In Experiment 1, participants compared the duration of LH against H. Psychometric functions revealed no bias between them. This suggests observers might overweight the dominant frequency channel (every stimulus includes an H), or were able to keep separate duration representations for each frequency channel and only use the H channel for judgments. In Experiment 2, LH was always presented first, followed by LH, H, or L. Duration of H was perceived longer than LH, consistent with a Bayesian cue integration model. Relative to LH, the judgments to H and L were significantly different, ruling out the model of separate duration representations. The precision of judging LH was better than H and L for the majority of participants. Experiment 3 used a static Gabor pattern (S) as the standard stimulus, and showed a compatible result. These data suggest observers weight duration information from multiple stimuli to form a single estimate. However, the distribution of stimuli in experiment context can influence the weights.

26.304 **Spatio-temporal structure of multi-focal MEG potentials shows evidence of striate global/local signalling.** David Crewther[1](dcrewther@swin.edu.au), Alyse Brown[1], Laila Hugrass[1]; [1]Centre for Human Psychopharmacology, FLSS, Swinburne University of Technology

Nonlinearities of the VEP, with signatures for magnocellular and parvocellular processing have provided useful insights into early cortical neural processing in normals (1) and autism spectrum (2). Signatures have been based on contrast response function, saturation and latency of response peaks. We extended these studies to magnetoencephalography (MEG). Five participants (young adult, 4 female, 1 male) observed a projected dartboard comprising 9 unstructured patches each executing pseudo-random binary m-sequences (VPixx). Four minute recordings on the 306 sensor Elekta Triux system were made at Michelson contrasts of 24% and 95% (60 Hz frame rate). Wiener kernel analysis (foveal patch) of the first-order K1 and the first two slices of the second-order kernel (K2 .1 & K2 .2) were characterized by an initial response latency of <50ms with major peaks with latencies of 95 ms (K1) 85 ms (K2.1) while the second slice (K2.2) demonstrated peaks rather more delayed in latency, similar to the electrical VEP. The early peak of the first slice K2.1 was already easily measurable with 24% contrast and did not grow at higher contrasts, indicative of the likely magnocellular origin. In a second experiment, a diamond illusion stimulus (3) was supposed over the randomly flashing central stimulus patch and participants reported global percepts (diamond shape oscillating horizontally) and local percepts (4 ungrouped moving lines) via pressing different buttons. Mean difference (Global – Local) magnetic evoked fields (MEF) showed little difference for times of <100ms, and a distinct peak with latency around 180ms centred over occipital cortex sensors. Thus perceptual rivalry exerts effects on the occipital MEF. References: (1) Klistorner A, et al (1997), Vis Res 37(15): 2161-9; (2) Sutherland A & Crewther DP, Brain 133: 2089-2097; (3) Fang F et al (2008), JVis 8(7):2, 2–9

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26.305 **Temporal Characteristics of the Straddle Effect (Buffy Contrast Adaptation) and Modeling with On-Off Neurons** Norma Graham[1](nvg1@columbia.edu), S. Sabina Wolfson[1], Carlyn A. Patterson[2]; [1]Dept. of Psychology, Columbia University, New York, [2]Dominick Purpura Department of Neuroscience, Albert Einstein College of Medicine, NY

Introduction. The appearance of a test pattern composed of two contrasts depends dramatically on the contrast of the adapt pattern immediately preceding it. If the test pattern's contrasts straddle the adapt pattern's contrast, the test pattern is extremely difficult for a human observer to perceive correctly. Our explanation of this psychophysical Straddle Effect has invoked a contrast comparison process that measures magnitude of contrast change but loses information about its sign. Methods. Each adapt and test pattern was a regularly-spaced 2x2 grid of Gabor patches. The spatial characteristics of all Gabor patches in adapt and test patterns were the same on all trials. In the adapt pattern the four Gabor patches all had contrast 50%. In the test pattern, two of the four Gabor patches had one contrast, and two had another. The two test contrasts varied from trial to trial. The duration of the adapt pattern, the duration of the gap (a gray screen) between the adapt and the test pattern, and the duration of the test pattern were varied. The observer had to say whether the arrangement of the two different test contrasts formed horizontal or vertical stripes. Results. The Straddle Effect was well developed with an adapt duration of about 50 ms. The effect was large with a gap duration of 0 ms and substantially diminished with a gap duration of about 50 ms. It was found for test durations varying from 12 ms to several seconds. Conclusion. These temporal results (along with spatial results reported last year) suggest the following: The contrast comparison process explaining the psychophysical Straddle Effect may result from On-Off neurons (neurons that respond transiently and positively to both increases and decreases in contrast) that have spatially-localized receptive fields. Preliminary modeling supports these suggestions.

26.306 **A neural correlate of the visual temporal-dilation aftereffect**

Jose Emmanuel Guzman-Martinez[1](emmanuelguz@gmail.com), Laura Ortega[1], Marcia Grabowecky[1,2], Satoru Suzuki[1,2]; [1]Department of Psychology, Northwestern University, [2]Interdepartmental Neuroscience Program, Northwestern University

We previously showed that several seconds of adaptation to a flickered stimulus makes a subsequently presented brief static stimulus appear longer in duration (Ortega et al., 2012). We investigated a neural correlate of this temporal-dilation aftereffect by recording event-related potentials (ERPs). Research in visual time perception has shown that stimulus duration is positively correlated with the peak latency of a negative ERP deflection, known as the contingent negative variation (CNV). If the visual temporal-dilation aftereffect alters duration representation in temporal mechanisms reflected in the CNV then the delay in the latency of the CNV peak should be positively correlated with the magnitude of the temporal-dilation aftereffect. We measured the magnitude of temporal-dilation aftereffects using a temporal-bisection task in which participants classified test stimuli (ranging from 200-800 ms) as closer to a short or to a long reference duration. In this paradigm, a shorter (left-shifted) point of subjective equality (PSE) indicates a longer perceived duration. Each test stimulus was randomly preceded by a flickered or static (control) adaptor, and the difference in the PSE between these adaptors indicated the magnitude of the temporal-dilation aftereffect. When the aftereffect generated a longer duration representation, the difference in the CNV peak latency (from the test stimulus onset) between the flickered and static adaptation conditions should be positively correlated with the corresponding PSE difference across participants. Indeed, we found a robust positive correlation between the CNV latency difference and the PSE difference ($r=0.758$, $t[11]=3.85$, $p<0.01$). Thus, the CNV peak latency provides a neural correlate of temporal dilation from flicker adaptation.

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26.307 **Abrupt transition between an above-CFF flicker and a stationary stimulus induces twinkle perception: Evidence for high-speed visual mechanism for detecting luminance change**

Yutaka Nakajima[1](nakajima@hi.is.uec.ac.jp), Yutaka Sakaguchi[1]; [1]Laboratory for Human Informatics, Graduate School of Information Systems, The University of Electro-Communications

Critical fusion frequency (CFF) gives a limit of our temporal visual processing; we cannot distinguish a stimulus flickering at a frequency above CFF (~60 Hz) from a stationary one (with the same subjective luminance) if they are presented simultaneously at different locations. When they are presented sequentially at the same position, however, a transient “twinkle” can be perceived (van Diepen et al., 2010). We assume that this “Transient Twinkle Perception (TTP)” is brought by the mechanism for detecting luminance change that is valid even above CFF. The purpose of the present study is to test this. In the experiment, donut-like stimuli (outer diameter: 4 deg, hole diameter: 2 deg) having a sinusoidal luminance profile were presented on a uniform background (50 cd/m2). Six participants were asked to discriminate TTP condition (sequential presentation of stationary and flickering stimuli) from no TTP condition (stationary stimulus only) by temporal 2-AFC. Maximum luminance of the stationary stimulus was fixed (65 cd/m2) while that of the flickering stimulus was manipulated; we prepared six luminance values of the off frame (50 – 62.5 cd/m2), and luminance of the on frame was calibrated by PEST for each participant to equalize the visibility between two stimuli. Temporal frequency of the flickering stimulus was also manipulated by choosing the vertical sync of the CRT monitor from 140, 150, and 170 Hz, and thus flicker frequency was either 70, 75, or 85 Hz. Participants could discriminate TTP from no TTP conditions in every temporal frequency condition, but correct rates were decreased as the luminance of off frame was increased (i.e., the luminance gap between on and off frames decreased). These results suggest that our visual system can detect transient luminance change above CFF, together with TTP is brought with a sufficient luminance gap between flickering and stationary stimuli.

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26.308 **Tracking the spatio-temporal propagation of entrained alpha oscillations across the visual field**

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Visual perception largely depends on the state of the brain at each moment in time. In particular, recent work demonstrated that the precise phase of ongoing alpha oscillations (~10Hz) at the onset of a target stimulus can predict whether this stimulus will be perceived or not. Here, we employ this alpha phase-dependence of perception in a psychophysical experiment to track the spatio-temporal propagation of entrained alpha oscillations across the visual field: is oscillatory phase invariant over space, or does it propagate like a travelling wave? In each trial, observers (n=9) fixated a central dot on the screen while a disc in the upper-left quadrant oscillated in luminance at the individual alpha frequency of each participant, so as to entrain an alpha oscillation with a specific spatial origin. Flash stimuli at perceptual threshold (adjusted via a staircase procedure) appeared at different positions (logarithmically spaced on the screen to achieve regular spacing on visual cortex) within the upper-left, lower-left or upper-right quadrants, and at different times with respect to the entraining oscillation. Flash detection was reported by pressing a button within a given time delay. We evaluated at each spatial location how the probability of flash detection varied along with the phase of the entraining oscillation. Detection performance presented a global oscillation that was detectable across the entire visual field, peaking around the ‘dark’ phase of the entraining oscillation. After subtracting this global effect, a significant oscillatory pattern of performance remained visible at several locations; its phase, however, varied significantly across locations, producing a travelling wave that propagated through the visual field. We conclude that it is possible to track, in a psychophysical paradigm, the spatio-temporal dynamics of the propagation of entrained alpha oscillations across the visual field. This propagation takes the form of a travelling wave, impacting perception in its wake.

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26.309 **The perceived onset of visual events**

Chris Paffen[1](c.l.e.paffen@uu.nl), Ryota Kanai[2]; [1]Experimental Psychology & Helmholtz Institute, Utrecht University, [2]School of Psychology, Sackler Centre for Consciousness Science, University of Sussex

What is the moment at which a visual stimulus reaches visual awareness? Previously, this question has been addressed by varying stimulus attributes such as contrast and intensity. These manipulations have shown differential effects on reaction times (RTs) and temporal order judgments (TOJs), which usually go in the same direction: stimulus manipulations that make RTs shorter also shorten perceptual latency for the stimulus measured in TOJ tasks. In our experiments, we manipulated the size of Gaussian blobs or Gabors of different spatial frequency presented left or right of fixation. In RT experiments, participants were instructed to indicate as soon as possible whether a target stimulus appeared left or right of fixation. In TOJ experiments, participants indicated which of two stimuli presented left and right of fixation appeared earlier. The results show that RTs are generally shorter for large stimuli, for both Gaussian blobs and Gabors of various spatial frequencies. On the other hand, the perceived timing of larger stimuli was delayed in TOJ experiments. Thus, when a large stimulus (e.g. 8 degrees in diameter) was presented simultaneously with a smaller stimulus (e.g. 1 degree in diameter), the larger stimulus was perceived to appear later. We suggest that the differential effects of stimulus size on RT and TOJ reflect separate neural mechanisms being used in both tasks. The effect of size on RT can be attributed to the increased signal of a larger stimulus. For the TOJ task, however, we suggest that the judgment of perceived timing is made based on synchronized activity over a larger cortical surface. The perceived timing of larger stimuli will be delayed, since increasing stimulus size will increase the cortical surface over which activity needs to be synchronized.

See page 3 for Abstract Numbering System

26.310 **Carryover effects in temporal bisection** Martin Wiener[1,2](m-wiener@gmu.edu), Branch Coslett[2]; [1]Department of Psychology, George Mason University, [2]Department of Neurology, University of Pennsylvania

Recent experimental evidence suggests that the perception of temporal intervals is influenced by the temporal context in which they are presented (Jazayeri & Shadlen, 2010). A longstanding example is the time-order-error (TOE), wherein the perception of two intervals relative to one another is influenced by the order in which they are presented. Here, we test whether the perception of temporal intervals in an absolute judgment task is influenced by the preceding temporal context. Human subjects (n=70) participated in a temporal bisection task with no anchor durations (partition method). Intervals were demarcated by a Gaussian blob (visual condition) or burst of white noise (auditory condition) that persisted for one of seven logarithmically spaced intervals between 300 and 900ms. Crucially, the order in which stimuli were presented was determined by a De Bruijn sequence (Aguirre, et al. 2011), such that all consecutive interval orders were counterbalanced. The results demonstrated a number of distinct findings. First, the perception of each interval was biased by the prior response, such that each interval was judged similarly to the previous choice. Second, the perception of each interval was influenced by the prior interval, such that perception was shifted away from the preceding duration. Third, the effect of prior interval was linear, such that more extreme intervals had a larger influence. Fourth, influence of the prior interval was negatively correlated with influence of the prior response, such that subjects with a large decision bias showed a smaller perceptual effect. Fifth, the effect of decision bias was larger for visual than auditory intervals. These effects extend TOE findings to absolute judgments, and demonstrate that temporal bisection is influenced by the immediate temporal context. Furthermore, our findings demonstrate that a single exposure to an interval can shift perception of a subsequent interval in a manner consistent with Bayesian and adaptation-level theory.

26.311 **A computational model of retinal circuitry predicts stimulus duration and intensity effects on visual persistence and afterimages** Jihyun Kim[1](kimj@psych.purdue.edu), Gregory Francis[1]; [1]Psychological Sciences, Purdue University

Visual persistence refers to a temporal characteristic of the visual processing in which a visual stimulus remains visible for up to a few hundred milliseconds after the stimulus physically disappears. Interestingly, a stimulus with higher contrast and/or longer duration persists shorter. While persistence is generally observed with 25~500ms of stimulation, negative afterimages (perceived images at the absence of physical stimulation that appear as weak polarity-reversed versions of previously presented stimuli) involve relatively long-term process and are typically observable only after more than few seconds of stimulation. Importantly, the effects of stimulus properties on afterimages are opposite to those for persistence such that a higher contrast and/or longer duration stimulus generates a stronger afterimage. While these two phenomena are important for investigating temporal vision and the seemingly related effects of the stimulus properties on them are intriguing, the underlying mechanisms producing these phenomena are unclear. In this study, we propose a theoretic /computational model that sheds light on the mechanisms of visual persistence and afterimages by simulating biologically plausible retinal circuitry for achromatic processing. According to the model, both persistence and afterimages are outcomes of a retinal light-gating process, which is largely determined by response kinetics and functional connections of horizontal and amacrine feedback layer cells onto the photoreceptor, bipolar, and ganglion feed-forward layer cells. Model simulations suggest that transient inhibition from the horizontal and amacrine cells to feed-forward layer cells differently shape ON and OFF ganglion cell responses and modulates persistence. On the other hand, afterimages are produced by slow changes of horizontal cell response kinetics that affect photoreceptors and bipolar cell responses to the background illumination. Overall, our results imply that the retinal circuitry decodes visual inputs into complicated temporal and spatial patterns, which consequently alter perceptual experiences.

26.312 **rTMS to right inferior parietal lobule dilates the subjective experience of time** Nicholas Peatfield[1](nick.peatfield@gmail.com), Lorella Battelli[1,2]; [1] Center for Neuroscience and Cognitive Systems, CNCS@UniTn, Italian Institute of Technology, Corso Bettini 31, 38068 Rovereto Italy , [2]Berenson-Allen Center for Noninvasive Brain Stimulation, Department of Neurology, Beth Israel Deaconess Medical Center, Harvard Medical School

Intro: A salient event embedded in a stream of serially presented identical stimuli can be perceived as lasting longer than its veridical duration. This subjective expansion of time (SET) might be due to the sudden allocation of attentional resources to the salient event (Tse et al., 2004). Recent studies on patients with damage to the right Inferior Parietal Lobe (rILP) suggest that this area plays a crucial role in the attentional network that is involved in discriminating events across time. In the present study we stimulated the IPL to understand its causal relationship with the subjective experience of time. We used an offline repetitive transcranial magnetic stimulation (rTMS) paradigm and measured SET before and after stimulation. Method: 10 participants took part in a 2AFC oddball discrimination task, in which they had to choose whether an infrequent 'oddball' (20% chance of presentation) of varying durations (staircase procedure) lasted "longer" or "shorter" compared to a frequent 'standard' (80%) constant duration (1050msec) stimulus. Each participant attended three counterbalanced sessions, where 10 min 1 Hz rTMS was administered on three different sites: rIPL, left-IPL and Occipital as a control site. SET was measured three times during each session: baseline before rTMS, post-rTMS and 30 minutes delayed-rTMS. Results: Analysis revealed a main effect of stimulation site, with an increased effect of the 'times expansion' factor after rIPL stimulation. Only after rIPL stimulation the 'oddball' had to be presented for a shorter time in order to be perceived to last the same amount of time as the 'standard'. TMS over left-IPL or Occipital had no effect. Conclusion: These data provide further evidence of the role of the rIPL in temporal processing of visual events. This function appears to depend on higher-order attentional mechanisms that are supported by the 'When' pathway of the right parietal lobe.

26.313 **The neural basis of temporal brightness effects** Hector Rieiro[1,2](hrieiro@neuralcorrelate.com), Maria Sanchez-Vives[3,4], Susana martinez-Conde[1], Jie Cui[1], Ramon Reig[3], Stephen Macknik[1]; [1]Barrow Neurological Institute, Phoenix, AZ, [2]University of Vigo, Vigo, Spain, [3]IDIBAPS, Barcelona, Spain, [4]ICREA, Barcelona, Spain

Our previous research has shown, using human subjects, that the relationship of contrast perception to stimulus duration follows the Broca-Sulzer effect, in which the perceived contrast shows a peak at a specific range of stimulus durations, as opposed to Bloch's Law, which predicts a monotonic relationship (Rieiro, et al. PNAS 2012). To determine the mechanistic pathways for this effect, we recorded from single units intracellularly and extracellularly in the primary visual cortex of cats and monkeys. We found in awake monkeys that the average response of neurons showed no (or little) change in the onset response, and that the after-discharge revealed an increase in magnitude followed by a decrease in magnitude of response that matched the Broca-Sulzer effect's timing. To determine the underlying mechanisms of this effect, we found with intracellular recordings in cat that onset responses to contrast–sign-matched stimuli show an unremarkable effect of duration (in correspondence with the monkeys), but that the termination response for contrast-sign reversed stimuli matched the Broca-Sulzer effect. This suggests that cells that process a specific contrast-sign signal the turning on of a stimulus, whereas the responses in the reverse contrast sign cells indicate the termination of that stimulus. The current model of brightness is that on-cells code the whiteness of a stimulus whereas off-cells code the blackness: on-cells signal white whereas off-cells signal black. Our data reveal that, instead, on-cells signal the onset of white stimulus whereas off-cells signal the turning off of a white stimulus. Further our data reveals a completely novel model in which the temporal effects of brightness are derived by the magnitude of the reverse contrast-sign pathway.

Acknowledgement: Fundacion Ibercaja, Science Foundation Arizona, National Science Foundation, Catholic Healthcare West, Barrow Neurological Foundation

26.314 **The neural correlates of flicker fusion** Stephen Macknik[1](macknik@neuralcorrelate.com), Hector Rieiro[1, 2], Jie Cui[1], Manuel Ledo[1], M. Reza Afrasiabi[1, 3], Susana Martinez-Conde[1]; [1]Barrow Neurological Institute, Phoenix, AZ, [2]University of Vigo, Vigo, Spain, [3]Creighton University, Omaha, NE

Artificial lighting and computer and TV displays rank among the most significant of all of modern society's innovations, and they all use flickering light, yet the neural mechanisms of flicker perception are unknown. Although each flash of a flickering stimulus in lighting devices are generally emitted for only a fraction of each flicker cycle, they appear as continuous and stable because we perceptually integrate successive flashes in a process called "flicker fusion". We determined the neural mechanisms for flicker fusion using single-unit recording of extracellular activity in area V1 of awake rhesus monkeys. Our stimuli were double-flashed gabor patches optimized to the orientation and position of the each receptive field tested, with varying flicker frequency and interstimulus interval. We found that the onset response to the second flash is practically eliminated in conditions where the interstimulus interval is very short, and it gradually recovers as this interval grows longer, irrespective of the flicker rate, implying that the interstimulus interval is more important parameter to flicker fusion than frequency. Likewise, correlated human psychophysics suggests that the suppression of stimulus transients results in flicker fusion. To further test this hypothesis, we predicted a new illusion, temporal fusion, in which we suppress a target's termination-response, using a mask, during a double-flash sequence, followed by suppression of the second flash's onset-response. This leaves solely the initial target's onset response and the final target's termination response, and the perception is a single long flash. This confirms that stimulus transients from the mask not only mutually suppress target transients (as we have previously found in visual masking experiments), but that long-term temporal filling-in occurs between stimulus on- and termination transients stimulus (in the absence of intervening transients), and that this is the fundamental neural correlate of flicker fusion.

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Visual memory: Encoding, maintenance, retrieval

Saturday, May 11, 2:45 - 6:45 pm

Poster Session, Royal Ballroom 6-8

26.315 The influence of top-down control over visual short-term memory

Claire E. Miller[1](claire.miller@bangor.ac.uk), Anna C. Nobre[2], Kimron L. Shapiro[3]; [1]School of Psychology, Bangor University, [2]Department of Experimental Psychology, New College, University of Oxford, [3]School of Psychology, University of Birmingham

Top-down goals, which are vital to success in everyday tasks, are thought to exert control over both visual cortex activation (Chelazzi, Miller, Duncan & Desimone, 2001) and cognitive processes such as memory (Sperling, 1960). However, it is unclear to what extent individuals can control the contents of visual short-term memory (VSTM). The current study presented two sequential 4-item displays per trial in a modified change detection task (Luck & Vogel, 1997), to examine participants' performance when prepared in advance to encode specified stimuli and when required to exert control mid task to change or maintain VSTM contents. Perfect top-down control over VSTM contents should allow similar performance whether prepared in advance or required to exert control mid trial. Results suggest participants perform similarly whether told early in the trial that they will be tested on the second display, or whether told mid trial to forget current (first display) VSTM contents and encode upcoming (second display) contents, $t(15) = -1.08$, $p = .297$. In contrast, participants perform significantly better when instructed early in the trial to remember only the first display, than when informed mid trial to retain the previous display and ignore the upcoming, $t(15) = 5.08$, $p < .001$. Control experiments using masked stimuli to minimize individual strategy, and increased post-cue processing time, revealed the same pattern of results. These findings build on previous evidence of top-down control over the encoding of items into VSTM (e.g. Sperling, 1960). We suggest that although participants can easily update VSTM contents, by removing old items and encoding new ones, they experience difficulty inhibiting encoding of irrelevant stimuli into VSTM, whilst maintaining relevant stimuli. Knowledge of the effectiveness of top-down manipulations throughout complex stimulus presentations is an important step towards developing information presentation strategies for optimal working memory storage, and informing future models of VSTM.

26.316 Witnessing the formation of a reportable working memory trace: Evidence from retroactive dual-task interference

Mark Nieuwenstein[1](m.r.nieuwenstein@rug.nl), Brad Wyble[2]; [1]Department of Experimental Psychology, University of Groningen, [2]Department of Psychology, The Pennsylvania State University

Through consolidation in working memory, the information that is extracted from a visual stimulus can be retained over time and distraction, thus affording a moment to reflect and report on what was in view only an instant ago. What is currently unclear is how long this consolidation process takes, whether it can deal with multiple stimuli in parallel, and whether it can continue after a stimulus has been erased from view by a trailing mask. Here, we report a series of experiments in which we addressed these matters by examining for how long the consolidation of one or more visual stimuli remains vulnerable to interference from a trailing event. Participants had to memorize masked or unmasked visual stimuli (letters or unfamiliar Kanji characters) that were shown simultaneously or sequentially and that could be followed within 100-1000 ms by an additional mask, a speeded detection task, or a speeded or unspeeded visual or auditory discrimination task. The main finding of interest was that the speeded discrimination tasks produced a pronounced retro-active interference effect for memory of the preceding stimuli. This interference effect occurred regardless of whether these stimuli had been masked, and it occurred regardless of the modality of the discrimination task. Most importantly, the magnitude of interference declined as the stimulus onset asynchrony increased from 100-1000 ms, reflecting the gradual formation of a memory trace strong enough to outlive the parity judgment. Taken together, the results suggest that visual working memory consolidation involves a relatively slow process that can deal with multiple stimuli in parallel, that continues after a stimulus has been masked, and that can then still be disrupted by a trailing second task.

26.317 Show Me the Features: Regular Viewing Patterns During Encoding and Recognition of Faces, Objects, and Places.

Makiko Fujimoto[1](makikof@stanford.edu), Kalanit Grill-Spector[2,3]; [1]Symbolic Systems Program, Stanford University, [2]Department of Psychology, Stanford University, [3]Neurosciences Program, Stanford University School of Medicine

Understanding viewing patterns of images is important for inferring how bottom-up and top-down information drive vision. However, it is unknown to what extent viewing patterns depend on specific features. Here, we examined subjects' eye movements during encoding and recognition and asked whether they are feature, view or task specific. During encoding, subjects viewed faces, cars and corridors in random order. Half of the stimuli were shown in the front view while the other half were shown in the side view. After a distracter task, subjects performed a recognition memory task and reported if images show an exemplar they had seen before or not, regardless of its view. Half of the images contained exemplars presented during encoding, and half were novel. Stimuli view was counterbalanced. In experiment 1 (19 subjects), stimuli view during encoding and recognition were identical. In experiment 2 (21 subjects), stimuli view during recognition and encoding were different. In both experiments, we found that subjects fixate on category-specific features (feature effect: Fs>174, Ps<10-6, 3-way ANOVA, factors of feature, view, and task): subjects look significantly more at the eyes and nose of faces, the front hood of cars, and the end of corridors. Furthermore, there is a significant interaction between the features and view: for faces, subjects fixate more at the nose for the front view, while at the cheek for the side view (Fs>7, P<10-6); for cars, subjects fixate more on the center of the hood for the front view, while at the near front hood for the side view (Fs>315, P<10-6); for corridors, subjects fixate more on the end of the corridor for the front view, while at the walls for the side view (Fs>260, P<10-6). These data demonstrate a regular viewing pattern driven by category-specific features that is modulated by the view of the stimulus.

Acknowledgement: NIH 1 R01 EY019279-01A1

26.318 There's good in disgust: Effect of an emotional memory priming on gustatory evaluation

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Many studies have reported that emotion could affect our hedonic evaluation of food. In order to investigate the origin of this effect, we have conducted an experiment in which the consequences of emotional memory priming on gustative evaluation have been assessed. In the Act-In model (Activation-Integration, Versace et al., 2009), memory traces are based on sensori-motor and emotional components. These traces are encoded and reactivated from perceptual experiences. In this view memory and perception would share the same neural substrates. Considering that both emotion and taste hold valence, we expected to find an effect of emotion priming on gustatory evaluation. In a first phase, participants associated a colour with a facial emotion (e.g. white with disgust, grey with joy). In the second phase, participants were provided pairs of ramekin (coloured in white and grey) containing different creamy dessert perfumes. Colour of the ramekin was used to prime the emotion previously associated with it. Participants had to judge the taste of the cream on a Visual Analogue Scale (from "I hate" to "I love") and also had to report different eating characteristics (e.g. eating vigilance, hunger state). Findings indicated that, for the cream they disliked the most, participants evaluated as better the creamy dessert contained in the ramekin for which the colour primed the negative emotion. Thus, this priming effect can be explained by an interference between mnemonic and perception activations due to the simultaneity of memory and perceptive treatments; so that valence memory and perception should share mechanisms (see Riou et al., 2011). In addition, many studies reported a strong link between food and motivational processes. Further analyses indicated that participants' eating characteristics modulated this interference effect. This impact of participants' characteristics could be attributed to differences both in the motivational processes and in attribution mechanisms of hedonic value.

26.319 Detecting a pop-out visual change can impair subsequent detection of another change in change detection
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According to previous studies of visual working memory, presence of an item that differs substantially from the remembered item in VWM can pop-out to trigger a shift of attention to the location of the visual change. What if detection of another change is necessary against the remembered items after that preceding change? In order to address this issue, we devised a change detection task in which two consecutive test arrays after a memory array were displayed in a way the change in the second test array can occur either at the same location as or at a different location from the changed item in the first test array. The results showed that detection of a change in the second test array went inaccurate only if the first test array had a change, and was impaired less if the change in the second test array occurred at the same location as the change in the first test array. These results indicate that detection of the preceding visual change can impair detection of a succeeding change, and the impairment would be larger if the subsequent change occurs at a different location from the preceding change. These suggest that a VWM-based pop-out change at one moment can suppress the pop-out of a change in the next moment, and the strength of the suppression relies on the spatial distance between the locations of the first and the second change.

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26.320 Comparison limits in change detection
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In studies of change detection, observers' ability to detect changes to an item in a display declines as set size increases. While the bulk of research has investigated the role of encoding and storage limits in change detection performance, less attention has been given to the role of comparison limits; that is, limitations on the rate or number of comparisons that can be made between test items and memory representations. Our study tested observers' change detection ability for 3, 6, or 9 coloured circles presented for 1000 ms, followed by a 500ms mask and subsequent 500ms blank screen. At test, 3, 6, or 9 coloured circles again appeared in the same locations as the sample display, and observers were required to report whether a change occurred to one of the circles (50% of trials). On some trials one or two cues were presented at test, indicating which coloured circles may have changed, thus reducing the number of comparisons needed between the test display and memory representations. Our results showed that detection ability for the one cue condition ($d' = 1.8$, $k = 2.7$) was significantly better than for the no cue condition ($d' = 1.6$, $k = 2.3$), $t(22) = 2.9$, $p = .008$ (d'); $t(22) = 3.07$, $p = .005$ (k). We also found that observers adopted a conservative change detection bias at set size 9 when not provided a cue ($c = 0.25$), which was reduced when a cue was provided ($c = 0.1$), $t(22) = 2.19$, $p = .04$. We conclude that comparison limits do contribute to the decline in change detection performance, and that when searching for changes at large set sizes, observers favour reporting no change due to increasing comparison uncertainty.

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26.321 Change detection in visual short-term memory: The relative impact of pairwise swaps and object substitutions
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The objects that feature in our visual environment undergo frequent changes. Object file theory (OFT) proposes that, across brief periods, we use visual short-term memory (VSTM) to detect these changes (Kahneman, et al., 1992). In this experiment, we investigated how two common types of change affected VSTM performance: object swaps (wherein two objects exchange locations), and object substitutions (wherein one or more objects are replaced by new objects). Fifteen participants completed two experiments. In both experiments, a study display comprised four 2° Snodgrass stimuli presented, for 400ms, at the corners of an imaginary 8° square. Concurrent verbal loading was used for articulatory suppression. Following a 1000 ms blank interval, a test display was presented. Participants indicated, via a yes/no button click, if study and test displays matched or did not match. In experiment 1, in 50% of trials, selected at random, a change occurred. This change was either a two-item swap, or a one-item substitution (fully counterbalanced). Experiment 2 was identical to experiment 1, except that in the object substitution condition, two objects (rather than one) were replaced. Percent correct performance data were analyzed using one-way repeated measures ANOVA, with change type (swap, substitution, or no change) as a within-subjects factor. In both experiments, a significant effect of change type on memory performance was observed [Experiment 1: $F(1.19,16.66)=70.68$, $p<0.01$; Experiment 2, $F(2,28)=21.75$, $p<0.01$]. In experiment 1, object swaps were detected more accurately than object substitutions ($p<0.01$). In experiment 2, an inverse pattern was observed: object substitutions were detected more accurately than object swaps ($p=0.02$). These findings extend OFT, suggesting that change detection when two extant object files are updated is easier than when one new object file is created. Conversely, change detection when two new object files are created is easier than detecting when two extant object files are updated.

26.322 Effects of meditation on decision bias induced by weak stimulus signals.
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Perceptual decision making has been extensively studied. It has been reported that past occurrence of weak signals significantly biases perceptual decision-making (Nishina et al., 2009; Kim et al., 2011). How can such biases be terminated? Here we investigated the effects of meditative states on decision biases induced by weak past stimulus signals. We examined whether this bias effect could be reduced or overcome by meditation. Participants were instructed to engage in either meditation or relaxation for 15 minutes before the test. The signal to noise ratio of the stimulus varied from trial to trial: four levels of signal were used. When the signal is zero, perceptual decision is solely based upon past sensory signals. We manipulated the probability of two stimulus alternatives of the weak signals. The results show that the magnitude of the effect of past occurrence on perceptual decision making was significantly smaller in the meditation condition than in the relaxation condition. These results suggest that meditative states reduce decision bias induced by weak signals.

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26.323 Forget all or hold all: Difficulty in selectively dropping items from visual working memory.
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Given the severe capacity limit of our visual working memory (VWM), it is crucial that we frequently update VWM representations depending upon the current task demands. Yet, it remains unclear how we "drop" no-longer necessary items from being held in VWM. Here, we measured the contralateral delay activity (CDA), a neural index of the number of items in VWM and asked participants to purge recently encoded items from VWM. In Experiment 1, we briefly (100ms) presented 4 colored squares and on some trials cued the participants during the retention period to either discard these items from memory. When the cue instructed participants to discard all four squares from VWM (i.e. forget-all condition), the CDA diminished completely following the cue. However, when a physically equivalent cue instructed participants to drop three items leaving one square remaining, the drop in the CDA was negligible. These results suggest that participants can delete all active VWM representations far more effectively than they can selectively drop a subset of items. In Experiment 2, we examined these same mechanisms under circumstances in which the stimuli remain continuously visible. Previously, we provided evidence that 1) we are subject to the same capacity limit even when the stimuli to represent are continuously visible, and 2) the capacity limit is manifested by the same neural correlate, the CDA (Tsubomi, Fukuda, and Vogel, VSS 2011). Using the same cue procedure as in Experiment 1, we replicated the finding that the CDA was almost entirely diminished in the forget-all condition. By contrast, however, we found a sizable CDA reduction even in the selective forgetting condition. These results suggest that we can selectively delete active VWM representations so long as the items are still visually available for resampling into memory.

26.324 Gradual encoding and decay in visual working memory
Hiroyuki Tsuda[1](tsudahiroyuqi@gmail.com), Jun Saiki[1]; [1]Graduate School of Human and Environmental Studies, Kyoto University

While capacity and representational format of visual working memory (VWM) have been extensively investigated, less is known about the processes involved in formation and decay of VWM representations. Zhang & Luck (2008) observed "all-or-none" transitions in VWM, proposing that participants store fixed-resolution representations of a subset of objects and retain no information about the others. Recently, we (Tsuda & Saiki, 2012) observed that memory precision varied depending on exposure duration of sample array, suggesting that precision of VWM is affected by how objects are perceived and consolidated, but precise temporal property remains unclear because of only a few duration conditions and of no proper control of duration with masks. In the current study we addressed whether tran-

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sitions in VWM encoding and decay are all-or-none fashion or gradually assembled during encoding and gradually lost during retention interval, and how stimulus complexity affects these processes. In Experiment 1, different groups of subjects were presented with either static bars or point-light walkers with variable presentation durations, and asked to remember them across a 1000ms retention interval. Unlike previous study, sample display was followed by a mask. In the bar task they recalled the orientation of a bar and in the walker task the direction-of-heading of a walker was recalled. In the walker task, we observed that memory precision gradually improved as the presentation duration increased from 500ms to 5000ms, while in the bar task presentation duration had no effect on precision. In Experiment 2, participants were presented with 4 point-light walkers and recalled the direction-of-heading of walkers across variable retention intervals. We observed a decline in memory precision for longer retention intervals, which suggests a gradual decay in VWM. We conclude that when remembering perceptually complex stimuli, memory precision evolves gradually during encoding phase and decays gradually during retention interval.

26.325 **Spatiotemporal priming facilitates visual-short term memory only in a forward-direction** Ian van der Linde[1, 2](i.v.d.linde@anglia.ac.uk), Shahina Pardhan[2], Raju Sapkota[2]; [1]Department of Computing & Technology, Anglia Ruskin University, Cambridge CB1 1PT, United Kingdom, [2]Vision & Eye Research Unit (VERU), Postgraduate Medical Institute, Anglia Ruskin University, Cambridge, United Kingdom

In this experiment, we investigated the impact of gaze-directed spatiotemporal priming on visual-short term memory (VSTM). One experiment with four conditions was completed by 17 participants. Our memory display comprised three 2° Snodgrass stimuli presented sequentially at random locations, each for 400ms. Participants fixated each stimulus in turn. Following a retention interval activity (see below), in our test display, participants were shown a single stimulus from among those previously presented, and responded (yes/no) to indicate if it had appeared in the preceding memory display at the same spatial position. Four (counterbalanced) experimental conditions were run, differing in the nature of a retention-interval activity: 1. a series of blank 2° spatial markers repeating the positions and durations of the memory display stimuli were fixated; 2. the spatial markers repeated the positions of the memory display stimuli, but were temporally reversed; 3. the spatial markers were presented at locations that were horizontally mirrored with respect to the memory display stimuli; 4. the spatial marker remained stationary at the screen center. To verify compliance, and suppress articulatory rehearsal, within each retention-interval spatial marker, a random 2-digit number was displayed, which participants spoke aloud. Performance data (percent correct) were analyzed using a two-way ANOVA, with retention-interval activity (4-levels) and the N-back index of the probed stimulus position (3-levels) as within-subjects factors. A significant main effect for retention-interval activity was found [$F(3,48)=15.97$, $p<0.01$]; no significant effect for N-back position was found, nor a significant interaction effect. Retention-interval activity 1 (spatiotemporal repetition) produced significantly greater performance than all other retention-interval activities ($p\leq0.01$). No other differences between retention-interval activities were significant. These results suggest that gaze-directed priming of the locations of to-be-remembered stimuli in a forward direction supports VSTM maintenance; temporally and spatially-reversed gaze-directed priming produced no benefit, being equivalent to the absence of any spatiotemporal priming.

26.326 **Task dependent memory recall performance of naturalistic scenes: Incidental memorization during search outperforms intentional scene memorization** Dejan Draschkow[1](dejan.draschkow@yahoo.com), Melissa L.-H. Võ[2], Ray Farmer[3], Jeremy M. Wolfe[2]; [1]Ludwig Maximilans University, [2]Harvard Medical School, BWH, [3]Union College

Memorizing critical objects and their locations is an essential part of everyday life. In the present study, incidental encoding of objects in scenes during search was compared to explicit memorization of those scenes. Participants were shown 10 different, indoor scenes. 150 objects (15/scene) were preselected. Regions of interest were defined around each object for eye tracking analysis. Observers searched for ten objects in each of five scenes (50 trials, mean RT=3550ms). For the other five scenes, observers spent 15 seconds memorizing as much as possible of each scene for later recall (task order and scenes assignments counterbalanced). We subsequently tested explicit scene memory in two ways. Global scene representation / boundary extension was assessed by showing observers previously-presented scenes and asking if the scene was closer-up or further away than the "original". Detailed scene memory was assessed by asking participants to redraw each of the 10 scenes and their objects. We found no indication of boundary extension for these complex, indoor scenes. Inferences about the scene beyond the image border did not become part of scene memory. Overall, a rather small percentage of the objects was subsequently drawn. Interestingly, even though participants in the search condition were not explicitly asked to memorize the scenes, they reproduced a substantially greater number of objects (22%) compared to the memory condition (11%). This advantage was produced by 29% recall of search targets, which received highest gaze durations (2600ms). Only 9% of all distractors were recalled despite mean gaze durations of 1730ms. Objects in the memorize condition were only looked at for 700ms, but 11% of these objects were recalled suggesting differential, task-dependent encoding strategies. Instructions to search for specific objects produced stronger encoding than the general request to memorize the scene even though the critical objects were repeatedly fixated in both conditions.

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26.327 **What's Feedback Got To Do With It? Examining Learning Rate and Generalization in Cross-scene Statistical Learning With and Without Feedback** Lauren Emberson[1](lemberson@bcs.rochester.edu), Patricia Reeder[1], Richard Aslin[1], Daphne Bavelier[1,2]; [1]Brain and Cognitive Sciences Department, University of Rochester, [2]FPSE, University of Geneva

Most models of learning predict that the presence of feedback facilitates the rate of learning, but can inhibit generalization by emphasizing attested exemplars rather than underlying rules. In a task where participants can learn statistical information without feedback (statistical learning), we examined what additional role feedback plays in learning and generalization. Following Shohamy and Wagner (2008), participants were taught arbitrary face-scene associations. On every trial, participants saw simultaneous presentation of a face and two scenes. After selecting one of the two scenes in a fixed response interval, participants were either given feedback (N=16, picture of a thumbs-up or -down) or not (N=19). Unbeknownst to participants, every two faces (Face1, Face2) were reciprocally paired with two scenes (Scene1, Scene2) creating a family of 4 overlapping associations (e.g. Face1—Scene1, Face1—Scene2, Face2—Scene1, Face2—Scene2). During training (4 blocks), participants were exposed to 3 of the 4 possible associations for each of the 16 families (trained associations). At test, feedback was always withheld to test for trained associations and untrained associations (generalization associations). There were robust and nearly identical learning rates for trained associations across feedback conditions. Both groups readily generalized but with marginally more generalization in the feedback condition ($p<0.1$). We find no significant difference in the frequency of non-learners across groups (defined as participants who fail to exhibit significant learning in any training block, feedback: N=2, no-feedback: N=6). Overall, these results show that learning of scene-pair associations and generalization to unseen, overlapping associations is minimally affected by the presence of feedback. In contrast to previous models, these results suggest that in the presence of salient statistical information, feedback may not modulate the time-course and outcomes of learning. Future work will examine how individual differences in the exposure phase affect learning rates and the factors that predict non-learners.

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26.328 **Mask Similarity Impacts Short-term Consolidation in Visual Working Memory** Lisa Blalock[1](lblalock@uwf.edu); [1]University of West Florida

Short-term consolidation is the process in which perceptual representations are stabilized into visual working memory (VWM) representations to prevent interference from subsequent visual input. Previous work has shown that when visual masks are presented soon after the offset of the memory array, memory accuracy is impaired especially with larger set sizes (Gegenfurtner & Sperling, 1993; Jolicoeur & Dell' Acqua, 1998; Vogel, Woodman, & Luck, 2006). Vogel and colleagues (2006) argued that visual masks overwrite the memory items when they have not been fully consolidated. However, in their experiments the visual masks were made of the same stimuli as the to-be-remembered items, which could have led to interference with controlled attention resources that select and maintain items in working memory (Engle & Kane, 2004). The current study examined how short-term consolidation is affected by the similarity of the subsequent visual items (i.e., visual masks) by using a color change detection task. In the task, masks were either similar or dissimilar to the memory stimuli and were displayed at varying intervals following the memory array. Similar masks were made up of the same colored squares as the to-be-remembered stimuli while dissimilar masks were black and white grids. Set size was also manipulated with participants viewing set sizes of 1, 2, 3, and 4 items. Results showed more interference from similar masks: similar masks required more time to consolidate and had lower overall performance compared to dissimilar masks. This pattern was especially true with larger set sizes. Overall, these results show very early involvement of controlled attention resources in VWM processing and suggest that an overwriting process cannot fully explain the interference from visual masks at brief intervals following the memory array.

26.329 Working memory consolidation does not necessarily delay response selection: Disentangling the costs of task initiation and execution Florian Sense[1](floriansense@gmail.com), Brad Wyble[2], Mark Nieuwenstein[3]; [1]Department of Psychometrics and Statistics, University of Groningen, [2]Department of Psychology, The Pennsylvania State University, [3]Department of Experimental Psychology, University of Groningen

Does working memory consolidation delay response selection? According to previous research, the answer is yes. The basis for this conclusion lies in findings that show a psychological refractory period effect (PRP) for response times (RT) for a second target that follows shortly after a first to-be-remembered target. The interpretation of this result is that memory consolidation and response selection both require access to a slow and capacity-limited processing mechanism. As a consequence, response selection would be postponed until the consolidation of the first target has been completed (e.g., Jolicoeur & Dell'Acqua, 1998). In the current study, we challenge this interpretation on the basis of the results of a study in which we compared the PRP effect between two conditions. In the standard condition, a single to-be-remembered letter was shown for 100 ms and followed at a stimulus onset asynchrony (SOA) of 100-600 ms by a digit that required a speeded parity judgment. In a second condition, the task was identical except that the blank interval separating the first and second targets was filled with an RSVP sequence of additional letters that each had to be reported at the end of the trial. As expected, the standard condition showed a decrease in RT with increasing SOA, reflecting a PRP effect. Strikingly, the RSVP condition revealed the same effect even though subjects were now consolidating additional letters into memory, and the number of letters encoded increased with SOA. These results show that the PRP effect is time-locked to the initiation of working memory consolidation upon detecting the first of a series of letters. This effect is explained in terms of an overhead cost associated with initiating the process of working memory consolidation.

26.330 Infants use statistical regularities to chunk items in visual working memory. Melissa Kibbe[1](kibbe@jhu.edu), Lisa Feigenson[1]; [1]Johns Hopkins University

Introduction. Infants' visual working memory (VWM) has a 3-item limit (Feigenson & Carey, 2003), but infants can "chunk" items using perceptually available properties, such as common features or spatial proximity, thereby overcoming that limit (Feigenson & Halberda, 2004; 2008). When such chunking cues are not available, adults can extract statistical regularities between visual arrays presented over time, and use these regularities to more efficiently group items in VWM (Brady, et al, 2009). Here we asked whether 13-month-old infants could also use statistical regularities between objects to increase VWM. Participants & Method. During 10 Familiarization trials, infants (N=21) saw 4 objects (red disk, blue cross, green pentagon, yellow squiggle) placed sequentially on a stage 2 at a time. In the No-Regularity condition, the objects were paired randomly on each Familiarization trial. In the Regularity condition, object identity was yoked such that, across Familiarization trials, the identity of one shape perfectly predicted the identity of the other. Next, infants saw 6 Test Trials in which all 4 objects were sequentially hidden behind an occluder, which was then removed to reveal either all 4 objects (Expected Outcome) or only 3 (Unexpected Outcome), on alternating trials. Results. As predicted by previous findings, infants in the No Regularity condition failed to look longer at the Unexpected Outcome when four objects were hidden and just three were revealed, $F(1,10)=0.005$, p=n.s.). This finding replicates earlier work demonstrating an upper limit on infants' VWM. In contrast, infants in the Regularity condition increased their looking to the Unexpected Outcome, $F(1,28)=6.37$, $p=0.024$ (see Figure 1). This suggests that seeing statistical regularities between individual objects allowed infants to group or chunk the objects in VWM, and hence to remember more total information about the scene. Conclusions. Infants can chunk items in VWM based on the statistical regularities present as events unfold.

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26.331 Reference frames in the integration of spatial information across views Tobias Meilinger[1](tm@fennel.rcast.u-tokyo.ac.jp), Katsumi Watanabe[1]; [1]Research Center for Advanced Science and Technology, The University of Tokyo

Humans can keep track of visual objects in an environment between different reference frames. Information about a view can thus agglomerate over glances. However, it is largely unknown how such multiple views are integrated, for example, the front- and backsides of a room never seen together. In order to examine the process of spatial integration, participants learned 2D arrays consisting of three objects during two screen presentations. In the first presentation they saw object A and B, in the second presentation object B and C. During the test they were presented with object A and asked to report on the location of object C. We manipulated the location and orientation of the array during the presentation and test. The participants performed generally better when the array was static throughout the presentation and test compared to when it moved. Current spatial memory theories focus on rotational costs and are largely silent about translational costs. However, the present results suggest that a simple translation of environmental reference frames does involve costs and therefore should be addressed more explicitly. The results further showed that the participants performed better when the orientation of the array during the test coincided with the orientation of the array in the first presentation than in the second presentation. This suggests that the participants integrated novel spatial information with respect to the reference frame of the previously seen information. When relating views through an object present in both views, the previously seen view seems to provide the stage for integration.

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Perception and action: Reaching and grasping, neural mechanisms

Saturday, May 11, 2:45 - 6:45 pm

Poster Session, Orchid Ballroom

26.401 Can't Touch This: Removing haptic feedback of the goal object during visually-guided grasping induces pantomime-like grasps Caitlin M. Byrne[1], Robert L. Whitwell[1], Tzvi Ganel[2], Melvyn A. Goodale[1]; [1]Department of Psychology, The Brain and Mind Institute, The University of Western Ontario, [2]Department of Psychology, Ben-Gurion University of the Negev

In a recent paper, Schenk (2012) argues that patient DF, who suffers from visual form agnosia following ventral-stream damage, uses haptic feedback to scale her grasps to the width of goal-objects to compensate for her profound visual deficit in perceiving their dimensions. Central to this claim is the fact that DF no longer scales her grip aperture in-flight to object width when the object is not actually grasped, despite directing her hand to the apparent position of the target viewed in a mirror. But it could also be the case that DF failed to scale because the absence of a felt object induced a shift in the nature of the task from real grasping towards something that resembles 'pantomimed' grasping, which is thought to be mediated by ventral-stream structures that are damaged in DF. Here we used Schenk's mirror apparatus to see if grasping in the absence of a real object in normal observers resembles pantomimed grasping. Twenty participants were asked to grasp or pantomime-grasp cylinders of different sizes viewed either in the mirror or directly through a transparent pane of glass. The slopes relating maximum grip aperture to object size for grasps directed towards an absent object viewed in a mirror were similar to those of pantomimed movements directed away from objects either viewed in the mirror or directly through glass. Importantly, grip scaling to object size in all three of these conditions was quite different from that observed in real grasping. Additionally, RTs were longer in the three 'pantomime' tasks, consistent with the view that pantomiming recruits additional cognitive mechanisms. These results suggest that removing haptic feedback of the object, even when participants reach to the perceived location of the target, induces a switch from real-time motor control to a more cognitively-driven strategy.

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26.402 The influence of crowding on grip scaling during grasping Juan Chen [1](jchen737@uwo.ca), Irene Sperandio[1,2], Melvyn Alan Goodale[1]; [1]The Brain and Mind Institute,The University of Western Ontario, London, Ontario, Canada, [2]The School of Psychology, University of East Anglia, Norwich, UK

It is well known that nearby objects influence the perception of a target (crowding), but little is known about how nearby objects influence our actions towards the target. In this study, a white disk of either 3 cm or 3.75 cm in diameter, was presented along the horizontal meridian at an eccentricity of 30° either in isolation (uncrowded) or surrounded by six disks of different sizes (crowded). At the beginning of each trial, LCD goggles worn by the participants were closed. Participants held down the start button with their thumb and index fingers pinched together. After the disks had been placed on the table, the goggles were opened. On perceptual trials, participants were required to manually indicate the size of the target disk using their thumb and index finger, and after that to pick up the disk. On grasping trials, participants were required to grasp the target disk with their thumb and index finger as quickly and accurately as possible. On some trials, the goggles were closed as soon as the start button was released (open loop) so that participants could not see their hands or the disks during the execution of the movement. On other trials, the goggles were closed 3 s after participants released the button (closed loop), permitting a full view of the moving hand and the target. In all tasks, the distance between the index finger and thumb was measured with OPTOTRAK. Even though participants could not indicate the size of the targets on perceptual trials, they scaled their grip aperture to the size of the target on grasping trials. These results were observed on both closed- and open-loop trials. Overall, these findings support the dissociation between vision-for-action and vision-for-perception – and suggest that the neural coding of objects may be different for these two systems.

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26.403 How to choose where to place the fingers when grasping a small bar: Effects of object weight and movement distance on grasp point selection

Vivian C. Paulun[1,2](Vivian.C.Paulun@psychol.uni-giessen.de), Urs Kleinholdermann[1], Karl R. Gegenfurtner[1], Jeroen B.J. Smeets[2], Eli Brenner[2]; [1]Department of General Psychology, University of Giessen, [2]Research Institute MOVE, Faculty of Human Movement Sciences, Vrije Universiteit Amsterdam

Choosing appropriate grasp points is necessary for successfully interacting with objects in our environment. Humans place their grasp axis near the center of mass (Lederman & Wing, 2003) to avoid large torques when lifting the object. Humans also generally attempt to minimize energetic costs (Alexander, 1997). We brought these two possible determinants of grasp point selection into conflict by asking subjects (N=21) to grasp elongated objects (10x3x1cm) that were approached from the side, and subsequently lift them. Minimizing energetic costs would result in a bias of the grasping axis towards the side at which the hand started. We used two clearly distinguishable objects with different mass (42.3 or 0.8g). The cost of grasping off-center will be higher for the heavy object, so the deviations from the gravicenter can be expected to be smaller. We indeed found a bias that was smaller for the heavy object. However, our right-handed subjects tended to grasp the objects to the right of the center of mass, irrespective of the starting position. We further investigated this effect in a second experiment (N=19). The rightward bias persisted when vision was removed once the hand was half way to the object, but grasp points may have been selected before then. The bias was reduced when subjects were instructed to place the object onto a small cylinder, as well as when subjects started their movement above the object. Letting our right-handed subjects grasp the objects with their left hand resulted in a leftward bias, so the bias appears to be related to the moving hand rather than to the movement direction. Thus, the selected grasping points seem to reflect a compromise between maximizing stability by grasping near the center of mass and grasping on the side of the acting hand, perhaps to increase visibility of the object.

26.404 Adaptation of reach-to-point movements changes reach-to-grasp actions

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Positioning the fingers on the opposite sides of an object is essential for a stable grasp. Most commonly, the thumb contacts the object on the visible part, whereas the other fingers enclose it on the occluded part. Given this functional asymmetry, we hypothesized that the different fingers play different roles in guiding the hand during reach-to-grasp actions. In the present study, we investigated if and how visuomotor adaptation of reach-to-point movements performed with the index finger or the thumb impacts grasping. Subjects were asked to reach for and grasp virtual objects (precision grip along the sagittal axis) without seeing their hand. Objects were random-dot elliptic cylinders with varying relative depth rendered in stereo and presented at different viewing distances with consistent vergence and accommodative information. Virtual instead of real objects were used to avoid proprioceptive/tactile feedback. The grasping trials block was always preceded by a block of reach-to-point movements towards a virtual rod positioned at a random viewing distance. Two factors were varied: (a) pointing finger − subjects pointed with either the index finger or the thumb; (b) visuomotor congruence − the visual feedback about the finger position either corresponded to the actual finger tip position (Congruent) or it was displaced farther in depth (Incongruent). Grasping behavior was measured after each of these four conditions. We observed a general transfer of visuomotor adaptation from pointing to grasping movements. The grasping hand was positioned at a closer distance after the incongruent than after the congruent visuomotor exposure. However, we found differential effects after index and thumb reach-to-point movements: visuomotor adaptation of the thumb affected grasping actions more strongly. These results provide evidence for a special role of the thumb in guiding the hand during reach-to-grasp actions and have implications on models for the control of reaching and grasping.

26.405 Preserved grip scaling to visual size despite non-veridical haptic feedback in a patient with visual form agnosia

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Compelling support for the two-visual-systems model (Goodale & Milner, 1992) comes from studies of patient DF who has visual form agnosia. Despite her inability to discriminate the form of objects, DF's in-flight grip aperture scales to the width of objects when she reaches out to grasp them. DF's perceptual deficits are thought to be a result of bilateral lesions in her ventral stream, while her spared visuomotor abilities are attributed to her relatively intact dorsal-stream structures. Schenk (2012) has recently argued, however, that DF uses haptic feedback "to compensate for her deficit in size perception". Using a mirror apparatus, Schenk found that DF failed to scale her grasp to objects of different sizes viewed in the mirror unless a corresponding goal object, which she could actually grasp, was present behind the mirror. When the object behind the mirror was absent, she failed to scale her grasp to the visual size of the objects (in contrast to normal controls). But it could also be the case that DF failed to scale because the absence of a felt object induced a shift in the nature of the task from real grasping, which is mediated by the dorsal stream, towards something that resembles 'pantomimed' grasping, which is mediated by the ventral stream (damaged in DF). Here we show that placing an object of constant size behind the mirror preserved DF's grip scaling for different sized objects viewed in the mirror – even though there was no veridical haptic feedback since the felt object was always the same size. These data suggest that the presence of a felt object is necessary and sufficient to engage DF's intact dorsal stream, allowing her to scale her grasp to changes in the size of a visible object – and that Schenk's earlier findings reflect DF's well-known inability to pantomime.

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26.406 Angular spatial updating of visually-previewed targets is more precise for nearer targets

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Many perceptual variables, like distance, are likely coded logarithmically such that we expect Weber's law to hold, but angular variables might not share this property. Limits in the precision of angular coding should be distance invariant. A directional error expressed at a far distance will represent a greater Cartesian displacement than at a near distance, but not a larger polar (angular) error. Nonetheless it appears to be subjectively more difficult to perform angular updating for larger distances when walking obliquely with respect to the target. To measure this, we used a facing task. On each trial, participants (N=37) walked blindfolded along a guide wire obliquely to a visually-previewed target until told to stop and were then asked to face toward the target. A compass was used to record facing direction. Similar geometries at scales of 6.6:1 were used for a far-space set-up and a near-space set up with final direction ranging from 55° to 90° with different scales being tested in random order. Variability in produced facing direction (i.e. mean SDs for 8 tested directions) was reliably greater for far targets (19°) than for near targets (13°), $t(7) = 3.22$, $p = .0027$. Because variability in perceived walking distance seems to follow Weber's law (Durgin et al., 2008), the greater angular error for farther distances suggests that the original visual encoding of egocentric distance might not follow Weber's law. Such a result is consistent with the use of angular variables (i.e., angular declination or gaze declination) to measure egocentric distance if we assume a small constant error in perceived straight ahead added to proportional noise in the coding of angular declination. In this scheme, small errors in the perceived horizon point could produce proportionally greater variability in perceived distance and therefore in angular updating for far targets than near ones.

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26.407 Reaching Into the Danger Zone: Specific Target-distractor Similarity Effects in Obstacle Avoidance

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The introduction of non-targets objects into a workspace leads to temporal and spatial adjustments of reaching trajectories towards targets. This is because target and distractor compete for attention during action planning. There have been several investigations into how this competition can be modulated by manipulating features of the distractor that are directly relevant for the movement, like size and orientation. On the contrary, little is known about the influence of features, like target-distractor similarity, that are irrelevant for the execution of the movement. In eye movement studies the similarity of distractors has been revealed to influence oculomotor competition. Because of the tight neural and behavioral coupling between the gaze and reaching system, our aim was to determine the contribution of target-distractor similarity to avoidance movements of the hand. We performed two experiments in which participants had to reach to grasp a target object while a distractor was present in the workspace. Experiment 1 featured a single target location, whereas Experiment 2 featured two target locations. The distractor could be either similar or dissimilar in color to the target. Moreover, the distractor was placed in several possible locations relative to the reaching hand. Kinematic parameters were extracted for analysis from the recorded hand trajectories. The results of both experiments indicate that dissimilar target-distractor pairs have a stronger effect on reaching-to-grasp movements than similar target-distractor pairs. This effect was most pronounced when the distractor was on the outside of the reaching hand. We propose that participants attended more to this specific location, or 'danger zone', as collision of the hand with the obstacle is more likely here, and that competition between target and distractor was enhanced. We conclude that target-distractor similarity, a feature not directly relevant for movement planning, can affect hand movements trough increased attentional capture by the distractor.

26.408 Local and global motion effects in interceptive timing

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Interception requires positional and velocity estimates of moving targets. Local motion affects the perceived position and velocity of static and moving Gabor patches respectively. However, the effect of local motion on action has been addressed with static Gabors or Gabors that underwent global retinal motion due to eye movements. I here address how local and global motion of moving Gabors affect action initiation and movement time. Targets were Gabor patches (SF=0.9 c/deg) that rotated clockwise with six possible global tangential velocities (2.9, 4.8, 7.9, 21.4, 58 deg/s). Using each rotational speed as a reference without local motion, I obtained the corresponding global speed that resulted in the same perceived speed when local motion in the same and opposite directions were added. For a given rotating speed I thus obtained 3 perceptually similar local motion conditions: without, same and opposite. Subjects then intercepted Gabors under these different conditions by controlling the horizontal position of a cursor with a polling device (sample rate 120 Hz). The interception had to occur when the envelope was between two reference horizontal lines. The initial Gabor phase was randomized across trials to avoid using positional local information. I recorded the position of the Gabor when the action started and when the cursor crossed the Gabor's path allowing to compute spatial and temporal errors and movement time. The position of the Gabors at action initiation was well explained by considering the local drift. That is, for a given rotational speed, subjects started moving when the target was at perceptually equivalent (but physically different) distances from the interception point. Interestingly, however, the movement time did not correlate with the perceived remaining time (considering local speed) but depended on the physical arrival time of the envelope. This reflects a different sensitivity to local motion for sensory and motor phases.

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26.409 Eye-hand coordination: Differential effects of obstacle position on reach trajectories, grasp and gaze locations.

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When we reach out to pick up an object, we rarely collide with any non-target objects, even if our workspace is cluttered. This seemingly simple task requires the coordination of motor, attentional, and perceptual systems. Even though previous research has investigated the effects of non-target objects on reach trajectories, their effects on eye-hand coordination remains to be determined. The current investigation utilized an eye-hand coordination paradigm, where a reaching and grasping task was performed in the presence of a non-target-object positioned exclusively in the right or left workspace of each right-handed participant. Non-target objects varied in their closeness to the subject and reach-path, between the starting location of the hand and the target-object of the reach. A control condition, where only the target was present, was also included. When non-target objects were presented on the right, greater reach durations and larger deviations in reach trajectories were produced than during the target-only condition. These effects increased further as the "obstacle" was placed closer to the subject or reach-path. Right-sided "obstacles" also pushed the final grasp and gaze locations on the target, shifting them to the left – away from the "obstacles". Unlike reach trajectory, final grasp and gaze locations were not influenced by the nearness of the non-target object to the subject or reach-path. As risk of collision increases for right-sided obstacles, a more trial-by-trial approach may have been taken to trajectory planning, though not in guiding the hand to the target. During trials in which non-target objects appeared in any of the leftward positions, none of these measures were affected. Results from the current studies demonstrate how the arrangement of clutter in an environment can differentially affect eye-hand coordination when reaching for an object.

26.410 Eye-hand coordination: Differential effects of object shape and surface properties on fixation and grasp locations

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Previous research has highlighted the importance of object shape and center of mass (COM) position in grasp location selection. For example, during a stable grasp, a subject's "grasp line" will fall close to or across an object's COM, with grasp locations shifting as a function of small COM changes. However, this research has typically utilized objects where the COM and the horizontal centre are very close in proximity, and has also ignored the characterization of fixation locations. In Experiment 1, we explored fixation and grasp location sensitivity to COM changes across object shape. The COM of objects was dissociated from the object's horizontal centre at three different distances (0.5cm, 1cm and 1.5cm). Results showed that orientation of COM was the largest influence on grasp locations, with no differences in grasp positions as a function of COM distance. Fixation locations were found to be more sensitive to changes in COM. Fixations to objects with COM distances of 1cm and 1.5cm were significantly further away from fixation locations to objects with the COM closest to the object's horizontal center (0.5cm). In Experiment 2, we kept the shape of the objects constant but varied the visual characteristics of the objects with gradients of luminosity (greyscale), numerosity (more to less stars), or area coloured (1/2, 1/3rd, or 1/6th of the object). Results showed a significant influence of the surface properties on grasp locations but not fixation positions. A rightward grasp bias was observed when grasping the greyscale and star objects. On the other hand, objects with 1/3rd and 1/6th of the surface area covered, biased grasp positions away from the coloured areas. Results from the current studies demonstrate how changes in object shape or changes in the local elements within a shape can differentially affect fixation and grasp locations when picking up an object.

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26.411 Perception and action are driven by a common representation of spatial features

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Goal: Spatial features of an object can be specified by use of symbols or motorically by directly acting upon the object. Is this response dichotomy reflected in a dual representation of the visual world: one for perception and one for action? Here we test whether motoric and symbolic specification of length and orientation rely on common or dual representations. Methods: One at a time, bars of different lengths and orientations were

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presented (47 ms.) on a monitor. Within trials, subjects first rapidly placed thumb and index finger at the endpoints of the bar. This motoric specification was measured with an optotrak system. Immediately thereafter subjects used a keyboard to indicate perceived length and orientation of the bar (symbolic specification). Results: The probability of making the same motoric and symbolic specification was well above chance for both length and orientation, indicating that a common representation was driving the two response types. Nevertheless, alternative explanations are possible. Discussion: Seeing or feeling the hand making the motoric specification might influence the symbolic specification, causing the high agreement between response types. A control experiment indicated that symbolic specifications of lengths were unaffected by the motoric specifications. Further, grasp precision of 3D objects does not follow Weber's law. This has been proposed as a marker for dorsal stream processing (Milner & Goodale, 2010). Ventral stream processing might drive the motoric specifications of 2D objects, also thought to drive symbolic specifications. If so a well-above-chance agreement of the two response types is expected. In the present experiment, the precision of the motoric specification, of the 2D objects, also did not follow Weber's law. Conclusion: the well-above-chance agreement between motoric and symbolic specification of both length and orientation is best explained by assuming that the two response types are driven by a common representation of spatial features.

26.412 **Memory-based bias for target selection transfers across different response modalities**

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Humans often select multiple objects in dynamic environments that require different modes of response (e.g., while driving, look at the clock, reach to the radio, etc.). Selection is biased towards recently attended target features; for example, participants respond to a unique red target faster if the previous target was also red (i.e., priming of popout). However, It is unknown whether the representation of this feature in memory is bound to a specific action, or whether a more broad representation of the feature alone, without a specific action association, biases selection. In a series of experiments, we examined this question by investigating the transfer of priming across different response modalities or even no overt response. In Experiment 1, cues instructed participants to respond to a uniquely colored target either by reaching to that target or by pressing a key based on the target's properties. Repeating target color on consecutive trials reduced keyboard response time, initial reach latency, and reach curvature, even when the response mode switched from one trial to the next (e.g. from a keyboard response to a reach response). In Experiment 2, target color repetition benefits occurred even following "no-go" trials in which observers had to withhold a keyboard response. However, while initial latency of reach movements was speeded following "go" trials, "no-go" trials biased selection only at the later movement stage by reducing reach curvature. Furthermore, in both experiments, the magnitude of the repetition benefit was diminished when the response mode switched. Together, these studies lend new insight into how memory biases selection and action, suggesting the existence of a high-level mechanism that biases target selection towards previous targets regardless of the previous response modality. However, the previous action does influence the magnitude of color repetition benefits, suggesting that it is represented at some level.

26.413 **Biased attention near one's own but not another's hand**

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Attention is prioritized for the space near the hand, leading to rapid detection of visual targets appearing close to one's own hand (Reed, Grubb, & Steele, 2006). We examined whether observers are also facilitated in detecting targets presented near another person's hand. Given that paying attention to a partner's hands is important for the successful coordination of joint actions (e.g., Sebanz, Bekkering, & Knoblich, 2006), we hypothesized that observers might also prioritize the space near another person's hand. In Experiment 1, participants performed a Posner cueing task while sitting next to a friend. Participants detected a peripheral target appearing to the left or right of a central fixation after a highly predictive visual cue. Across blocks, either the participant or the friend placed a hand next to one of the target locations. We also included a no-hand condition in which both the participant and friend sat with their hands away from the screen. The results showed that participants detected targets appearing near their own hands more quickly than targets appearing away from their hands. However, participants were no faster to detect targets appearing near a friend's hands than targets appearing in the no-hand condition. In Experiment 2, we increased the visual similarity between hands by having participants and their friends wear the same rubber gloves. Again, participants were facilitated in detecting targets near their own hands, but not near their friend's hands. Therefore, although joint attention is important for action coordination, the mere presence of another person's hand is not sufficient to bias attention. In sum, our data support the notion that space near one's own hand is prioritized for attention. However, the effect of hand proximity on spatial attention is specific to one's own hand but not another's hand.

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26.414 **Interactive effects of hand-proximity and emotion on vision**

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Recent research has revealed that there are remarkable changes in vision for stimuli near the hands. However, the mechanisms underlying these changes remain unclear. We present research suggesting that the mechanism underlying changes in vision for stimuli near the hands may be similar to the mechanism activated following exposure to emotional stimuli. In Experiment 1 participants detected the orientation of high spatial frequency (HSF) and low spatial frequency (LSF) gabor patches with their hands near and far from the stimuli. Just as LSF sensitivity is enhanced following exposure to fearful stimuli, we found LSF sensitivity was enhanced for stimuli near the hands. These data imply that activity in the magnocellular channel, which primarily processes LSF information, is enhanced for stimuli near the hands just as it is for emotional stimuli. In Experiments 2 and 3 we demonstrated that reducing magnocellular processing (by exposing participants to diffuse red light) eliminated effects of hand nearness on vision. Specifically, in Experiment 2, against a red background participants showed no differences in spatial frequency sensitivity across hand positions. Furthermore, in Experiment 3 participants performed a visual search task (for a letter target amongst distractors) on both a green and a red background. Against the green background, we replicated the typical finding of slower rates of search for stimuli near the hands. However, against the red background hand position did not modulate search rates. Finally, in Experiment 4 we directly investigated the interaction between hand position and emotion. When participants searched for a target embedded in a fearful or neutral image, effects of hand position and emotion interacted, indicating that emotion and hand nearness may act through a similar mechanism. Specifically, whereas accuracy was poorer for neutral images in the hands-far condition, when hands were near the stimuli accuracy did not differ based on emotion.

26.415 **Goal understanding in non-human primates: active action categorization tasks.**

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Previous electrophysiology and imaging studies in monkeys (Perrett et al., 1989; Fogassi et al., 2005; Nelissen et al., 2011) looking into the neuronal correlate of action understanding, have shown brain responses during passive action observation in superior temporal sulcus, parietal, premotor and frontal regions. However, from these studies it is difficult to draw conclusions on the monkeys' ability to understand the goal of the observed action, since these experiments required only passive fixation. Therefore, using active categorization tasks, we investigated rhesus monkeys' ability to categorize videos of hand-object actions according to the goal of the action. Rhesus monkeys were trained to categorize videos according to the goal of the action (grasping versus not-grasping). After a 3 sec video presentation, the video disappeared and was followed by presentation of two peripheral target points. Monkeys were required to make either a leftward or rightward saccade, depending on the goal depicted in the action video (grasping or not-grasping, respectively). After performance on the categorization task was proficient, monkeys were tested on their ability to generalize to other untrained grasping or not-grasping actions. After training, performance on the categorization task was above 90% correct. More importantly, generalization tests demonstrated monkeys' ability to recognize the goal of the action depicted in the videos, even for a wide range of untrained videos. Monkeys were proficient at correctly categorizing both new untrained grasping actions with different grip types, objects or biological effectors (either a male human or monkey hand), as well as new not-grasping actions including mimicked grasps and open hands touching the object. However, monkeys failed to generalize to videos showing an artificial prosthetic hand grasping an object. These results demonstrate the feasibility to use cognitive more demanding active action recognition tasks in rhesus monkeys to investigate the neuronal correlates of action understanding.

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26.416 **Neural correlates of target encoding for memory-guided reaching.** Gordon Binsted[1](gordon.binsted@ubc.ca), Darian Cheng[1]; [1]School of Health and Exercise Sciences, University of British Columbia

In this study, the neural correlates associated with target encoding during visually guided and memory guided reaching were examined. Participants performed aiming movements using a stylus on a graphics tablet with visual stimuli projected onto a mirror positioned above the aiming surface. For the experimental protocol, individuals were provided with a 100% predictive cue followed by a brief preview of a target. The cue was indicative of the events that would occur after the preview of the target. Specifically, the delay period between the offset of the target preview and the imperative stimulus to move (i.e., 2s or 5s delay), and also whether the target would reappear when the imperative stimulus was presented (i.e., FV or NV). Event related brain potentials (ERP) associated with target encoding (i.e., target preview period) were averaged and compared across vision and delay conditions. Kinematic analyses were also used to examine the behavioural manifestations of the reaches. Results from the ERP analysis during target encoding revealed differences of brain activity based upon expected availability of vision; these differences occurred at time-points consistent with motor plan formation and updating (i.e. N2-P3, Kourtis et al 2012). At later epochs, there was a further modulation of activity based upon the expected delay condition, independent of visual condition. Corresponding behavioural results were in-line with previous memory guided reaching experiments. In all, the expected conditions under which a movement will be made significantly influences the manner of target encoding.

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26.417 **Preparatory neuronal activity for reaching: movement planning, target location, and attentional signals converge in macaque medial posterior parietal cortex** Patrizia Fattori[1](patrizia.fattori@unibo.it), Rossella Breveglieri[1], Giulia Dal Bo'[1], Kostantinos Hadjidimitrakis[1], Federica Bertozzi[1], Claudio Galletti[1]; [1]Dept. Pharmacy and Biotechnology, University of Bologna

Posterior parietal cortex (PPC) in humans and monkeys contains many reach-related areas, and V6A is one of them. Although several fMRI studies in humans found reach planning activations in regions putatively homolog to monkey V6A (Galati et al., 2011; Gallivan et al., 2011; Bernier et al., 2012), the involvement of this area in encoding reach intentions has never been explicitly demonstrated. Here, we addressed this issue by comparing the activity of single cells during the instructed delay period in a reaching and a fixation task, performed in separate blocks. In these tasks, the animals were fixating targets arranged in 3D space and waited for a Go cue to reach (reaching task), or release a button (fixation task). We found different types of cells: cells modulated by the fixation of a target regardless of whether it was reached or not (25%), cells modulated only by reaching preparation (17%), and cells influenced by both signals (44%). Reach preparation cells often showed a congruent spatial tuning during movement execution. Most cells showed lower delay activity before reaches compared to before button releases, whereas a minority showed the opposite effect. The timing of excitation, but not that of inhibition, was time-locked to reach onset. We propose that inhibition could derive from changes of attention/alertness associated with preparing a reaching movement, whereas excitation reflects reach planning. In agreement with human fMRI studies, cells involved in reach planning are less in V6A than in nearby parietal reach region (PRR), suggesting common neuronal mechanisms for reach planning in monkey and human medial PPC. In V6A, reach planning signals coexist with target location and attentional signals. We propose that before reaches, while PRR encodes the intention to reach, V6A is more involved in processing various inputs to localize reach targets in the 3D space.

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26.418 **The P300 component and the visuomotor mental rotation task: context-updating scales to angle of rotation** Matthew Heath[1](mheath2@uwo.ca), Stephane Maclean[2], Cameron Hassall [2], Olav Krigolson[2]; [1]School of Kinesiology and Graduate Program in Neuroscience, University of Western Ontario, [2]Department of Psychology and Neuroscience, Dalhousie University

The visuomotor mental rotation (VMR) task elicits a reliable increase in response latencies as a function of increasing (and perceptually unfamiliar) angles of rotation (Georgopoulos and Massey 1987: Exp Brain Res; Neely and Heath 2010: Brain Res). Evidence from non-human primates suggests that the increased latencies reflect a monotonic rotation of neural population vectors within frontal motor areas. The present investigation evaluated the behavioural and event-related brain potentials (ERP) associated with the VMR task to determine whether accurate performance is related to a remapping of the environmental parameters of a target or a shift of visual attention from a veridical to a cognitively represented target location. Twenty human participants were provided advanced information to complete a direct (i.e., 0°) or VMR response (35, 75 and 105°) to each of eight concentric targets. Targets were presented for 1,000 ms in advance of response cuing and ERPs were locked to their presentation. Behavioural results indicated that endpoint accuracy and variability increased with increasing angle of rotation. In terms of ERP findings, an early component (i.e., N100) related to the orientating of visuospatial attention did not differ across the VMR tasks. In contrast, the amplitude of a later occurring component (i.e., P300) scaled with increasing angle of rotation, and the amplitude of this component increased with increasing endpoint variability. Importantly, previous research has linked the P300 to a revision of an internal mental model when a mismatch exits between a visual stimulus and a required task goal (i.e., context-updating). As such, we propose that the VMR task is mediated via a top-down and cognitively based reformulation of action space, and that such a process occurs well in advance of response cuing. Moreover, the conjoint behavioural and ERP findings suggest the degree of context-updating decreases the effectiveness of the motor response.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada

26.419 **Double dissociations of Magnocellular and Parvocellular Pathways in Processing Global Topological and Local Properties** Yan Huang[1](yhuang@bcslab.ibp.ac.cn), Tiangang Zhou[1], Lin Chen[1]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Biophysics, Chinese Academy of Sciences

The magnocellular (M) and parvocellular (P) pathways are segregated in anatomy as early as from the retina and lateral geniculate nucleus, as well as in function with M pathway conveying low-resolution information rapidly and P pathway conducting fine details slowly. Evidence shows that fast M projections facilitate object recognition via top-down modulations. Previous studies suggest global topological properties (TP), to which the visual system is highly sensitive, might serve as the starting point for the formation of object representations. Here we hypothesize that M pathway may contribute to fast object recognition by extracting TP in a visual scene and initiating a feedforward process, in addition to indirect feedbacks. We adopted unconscious response priming, a paradigm extensively used in studies on early vision, and used stimuli that were either of achromatic low-luminance contrast (M-biased), or chromatically defined and isoluminant (P-biased), to examine whether the processing of TP (e.g., number of holes) and other local properties (e.g., orientation) dissociate in the two pathways. To avoid potential confounding, we matched area and spatial frequency of stimuli. We found that priming effects of TP occurred with M-biased stimuli rather than P-biased ones, in both TP-relevant (i.e. discriminating no-hole from one-hole stimuli) and -irrelevant tasks (i.e. judging the orientation). Conversely, priming effects of orientation were observed only for P-biased stimuli, and only when orientation report was explicitly required. Moreover, the average response times (RTs) were shorter for TP judgment than those for orientation, and RTs were shorter for TP when stimuli were M-biased than when P-biased. Further measurement for prime identification showed neither of these properties in prime could be discriminated. Our findings suggest that M and P pathways are dissociated at the early stages of visual process, with M engaged in fast global TP extraction while P in slower local feature identification.

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Motion: Neural mechanisms and models

Saturday, May 11, 2:45 - 6:45 pm
Poster Session, Orchid Ballroom

26.422 How and why do image frequency properties influence perceived speed?

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Humans are able to interact successfully with moving objects in our dynamic world and the visual system efficiently performs the motion computation that makes this possible. Object speed and direction are estimated following the integration of information across cortical motion sensitive channels. Speed estimation along this system is not fully understood, particularly the mapping function between the actual speed of viewed objects and that perceived by observers, a question we address in this work. It has been demonstrated that perceived speed is profoundly influenced by object contrast, spatial frequency, stimulus complexity and frequency bandwidth. In a 2 interval forced choice speed discrimination task, we present a random phase textured motion stimulus to probe small shifts in perceived speed measured using fixed stimulus sets as reference scales while mean spatial frequency and bandwidths serve as the dependent variable in a probe. The presentations are short (200ms). Using a scale of narrowband stimuli (0.2 octaves), we measured a shift in perceived speed; higher frequencies are seen as faster moving than lower ones. On the scale of broader bandwidth (1 octave), this difference across frequency was reduced and perceived speed seems to converge on a slower representation. From these results we estimated this mapping between perceived and veridical stimulus speeds. In direct comparisons, the relative speed is faster for high frequencies and increases in bandwidth make stimuli appear slower. During this early computation, when presented with a random phase stimulus it appears that the visual systems makes assumptions about expected speeds based on the richness of the frequency content and the veridical speed is not explicitly computed. In this first 200ms, the perceptual system perhaps underestimates some speeds in an optimal response for initially stabilizing the scene.

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26.423 Effect of contrast and prior expectations in human speed perception

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The perceived speed of moving objects has long been known to depend on image contrast. Lowering the contrast of first-order motion stimuli typically decreases perceived speed – the well-known “Thomson effect”. It has been suggested that contrast-dependent biases are the result of optimal inference by the visual system, whereby unreliable sensory information is combined with prior beliefs. The Thomson effect is thought to result from the prior belief that objects tend to move slowly rather than quickly (in Bayesian terminology, a “slow speed prior”). However, a subset of the relevant literature has presented conflicting evidence – the attenuation or even reversal of the Thomson effect at higher speeds (temporal frequencies >8 Hz). Does the effect of contrast on perceived speed depend on absolute speed and what does this imply for Bayesian models with a slow speed prior? 6 subjects compared the speeds of simultaneously presented drifting gratings of different contrasts in 2100 trials. The speed of one grating was fixed at one of four levels (1, 4, 8, 12 deg/s) whereas the speed of the other was adjusted via a staircase procedure until perceived speeds matched. The Bayesian model of Stocker & Simoncelli (2006) was used to extract the subjects’ speed priors. At low contrasts (1-6%), we found that the Thomson effect was attenuated at high speeds: at 8 and 12 deg/s, perceived speed increased less with contrast than at 1 and 4 deg/s; however, at higher contrasts (6-70%), the situation was reversed. Furthermore, the extracted priors were not monotonically decreasing for all subjects. These novel findings regarding the interactive effect of physical speed and contrast on perceived speed as well as the hitherto unobserved non-monotonicity of the speed prior help reconcile existing conflicting literature and suggest significant inter-individual differences in the speed prior, possibly mirroring differences in individuals’ experiences.

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26.424 Motion Silences the Perception of Changing Image Quality in Naturalistic Videos

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Failure to detect changes in stimulus luminance (or color, etc.) termed “silencing” occurs in the presence of rapid motion (Suchow and Alvarez, 2011). It is possible that silencing is useful in naturalistic contexts, serving to suppress the perception of cast shadows on moving objects, say, or preventing video artifacts from being distracting. We conducted human experiments examining the perception of “flicker” caused by variation in image quality for moving objects in videos. 42 naive subjects evaluated the amount of perceived flicker of moving objects in the random ordered 36 test videos, which included six flicker-free reference videos and 30 degraded, flickering videos. The flicker was generated by alternating video frames of different quality levels (e.g.: bad, poor, good, and excellent). An eye and head tracker (faceLAB 5, Seeing Machines) was used to monitor gaze position (subjects’ heads were unrestrained), and subjects reported their percepts by moving a mouse continuously throughout the stimulus presentation. The results indicate that the reduction of the visibility of flickering in natural videos depends on both the overall video quality and the speed of motion. When the video quality was high, the perceptual visibility of flickering is low and less sensitive to motion, whereas when the video quality was poor, the impact is large. Furthermore, although subjects held their gaze on the moving objects, less flicker was seen on fast-moving objects. We interpret this result to suggest that large coherent motions near the fixation point might silence the awareness of flickering on natural videos. The responsible mechanism might be useful in the real world, where the light coming from moving objects can change dramatically (due to passing through areas of light and shadow, e.g.) even for a rigid object with a constant trajectory.

Acknowledgement: This work was supported by the Intel and Cisco Corporations under the VAWN program and by the National Science Foundation under Grants IIS-0917175 and IIS-1116656.

26.425 Exploring the spatiotopic frame using motion after-effects

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Motion after-effects have been used to probe the existence of spatiotopic map. Turi and Burr (2012) reported spatiotopic adaptation using a single adapting stimulus. If a true spatiotopic map exists then it should be possible to simultaneously adapt two points in separate locations within the putative map. Our preliminary work established that we could obtain adaptation to a single patch and separate patches that could be based on either a retinotopic or in a spatiotopic reference frame. We then tested whether we could obtain adaptation to two adapting patches positioned in different parts of the spatiotopic frame. The build up of motion adaptation was measured with a nulling procedure (staircase run over sessions following Bex et al., 1999) at 5 intervals during the adaptation (total adaptation period of 50s). Participants adapted to a 5deg stimulus composed of 300 dots moving radially inwards or outwards (median 3 deg/sec). In two adapting patches experiments the stimuli were separated by 20deg and had opposite direction radial motion. We obtained adaptation to a single patch positioned in either a retinotopic and spatiotopic frame; and we obtained adaptation to two patches separated in a retinotopic frame. At a group level, there was evidence of adaptation to two separate patches in a spatiotopic frame; but the magnitude of this adaptation was relatively weak and there were notable individual differences.

Acknowledgement: School of Psychology

26.426 Transcranial electrical stimulation affects adaptation of MT/V5 neurons in awake behaving macaques

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Despite widespread use in clinical and behavioral studies, the mechanisms of action of transcranial electrical stimulation (tES) are poorly understood. We partially attribute this to the lack of in-vivo animal models and have started to probe the influence of tES on the well-explored macaque visual system, specifically area MT. Previously we have shown that tES reduces the motion aftereffect in human subjects. This leads to the hypothesis that neurons adapt less during tES. To test this, we recorded from adapted and unadapted MT cells, with and without tES. In the adaptation condition, we presented an adapter stimulus (dots moving coherently in the cell’s preferred direction) for 3s, followed by a 300ms blank period, and then a

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300ms test phase (dots moving in one of eight evenly spaced directions). In the stimulation conditions we applied transcranial alternating current stimulation (tACS; 10 Hz, 1 mA) during the adapter stimulus across two electrodes placed extra-cranially on either side of the recording chamber (over area MT). In the control (non-adapted) trials, the adapter was replaced by a noise stimulus consisting of dots moving in randomly chosen directions. At single cell level, we found that tACS induced statistically significant changes in adaptation as measured by subsequent response to the test stimuli (tuning amplitude, width, and preferred direction). However, these effects were quite heterogeneous across the population, with tACS increasing adaptation of some cells and decreasing adaptation of others. It is not yet clear how these neural changes relate to the behavioral changes we reported in humans. Our approach establishes the awake behaving macaque as an animal model to study tES. This important step will allow us to relate tES-induced neural changes directly with behavioral changes and provide a mechanistic insight into the neural mechanisms of action of tES.

Acknowledgement: The Pew Charitable Trusts, The Charles and Johanna Busch Memorial Fund at Rutgers University, and The National Eye Institute (EY017605)

26.428 **Visual regions V2, V3, and MT can discriminate between visual motion trajectories even when you can't.** Diana Gorbet[1](dgorbet@alumni.yorku.ca), Frances Wilkinson[1], Hugh Wilson[1]; [1]Centre for Vision Research, York University

Radial frequency (RF) motion trajectories are a class of visual stimuli that consist of a target moving along a closed trajectory defined by a sinusoidal variation of the radius relative to a circular path. The results of a previous fMRI multivoxel pattern analysis study demonstrated that trajectory shape can be distinguished in regions V2 and V3 for radial frequency patterns ranging from RF2 to RF5 (Gorbet, Wilkinson, and Wilson, 2012). These low frequency trajectories formed recognizable shapes that were oval-, triangle-, diamond-, and star-like. These results indicate that V2 and V3 have a role in processing closed-circuit visual motion but do not reveal whether discrimination involves encoding global categories of shape or more local differences in trajectory curvatures. If a region is involved in recognizing the overall shape of a trajectory, multivoxel pattern discrimination should disappear for high frequency trajectories that form non-discriminable shapes. In the current study, we used a multivoxel pattern analysis fMRI approach to test this prediction. In particular, we tested whether patterns of voxel activity in independently localized visual regions could distinguish both between recognizable RF4 and RF5 trajectories and between unrecognizable RF9 and RF10 trajectories. As expected, RF4 and RF5 trajectories could be reliably distinguished in regions V2, V3, and additionally, in region MT. However, the data revealed that these same regions can also discriminate between RF9 and RF10 trajectories even though separate psychophysical testing indicates that observers cannot tell these motion trajectories apart any better than chance. These results suggest that distinguishing between different RF motion trajectories in regions V2, V3, and MT relies on local properties of trajectory curvature. Preliminary further examination of the data using a whole-brain recursive feature elimination approach suggests that perception of global trajectory shape may occur in higher level parietal and frontal cortical regions.

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26.429 **The detection of counterchange, not motion energy, accounts for coherent motion perception in random-dot cinematograms** Joseph Norman[1](jnorman@ccs.fau.edu), Howard Hock[1,2]; [1]Center for Complex Systems and Brain Sciences, Charles E. Schmidt College of Science, Florida Atlantic University, [2]Department of Psychology, Charles E. Schmidt College of Science, Florida Atlantic University

It is well-known that the coherent displacement of a sector of a random-dot cinematogram results in the perception of motion in the direction of the displacement (the short-range motion effect; Braddick, 1974; Lappin & Bell, 1976), and that motion in the direction opposite to the displacement, so-called reverse-phi motion, is perceived when the displacement is accompanied by the reversal of luminance polarity (Anstis, 1970; Sato, 1989). These motion phenomena have commonly been attributed to the extraction of motion energy, with the further implication that figure segregation and the perception of shape-from-motion likewise depends on motion energy extraction (Dosher, Landy & Sperling, 1989). Our psychophysical and computational results cast doubt on the role of motion energy extraction in this paradigm. We have confirmed, first of all, that the discrimination of both motion direction and figure shape are better in the standard than the reverse-contrast conditions. This asymmetry is inconsistent with the elaborated Reichardt detector (van Santen & Sperling, 1985), which predicts equally strong and coherent motion in the standard and reverse-phi directions. In contrast, the counterchange detector, which signals motion through the detection of oppositely-signed changes in contrast for pairs of edge detectors (Hock, Schöner & Gilroy, 2009), is sensitive to the asymmetry in standard and reverse-phi motion. Both trial-by-trial and full-experiment simulations indicate that a motion architecture based on the counterchange principle is sufficient to plausibly account for the observed asymmetries in both motion direction and shape discrimination, including the perception of motion in the reverse-phi direction. In conclusion, counterchange detection rather than motion energy extraction is the likely basis for the short-range motion effect, and for figure segregation and the recovery of shape from coherent motion.

26.430 **Neural correlates of speed-tuned differences in global motion and motion-defined form perception** Kimberly Meier[1](kmeier@psych.ubc.ca), Marita Partanen[2], Ryan Lo[3], Deborah Giaschi[3]; [1]Department of Psychology, University of British Columbia, [2]Department of Educational & Counselling Psychology & Special Education, University of British Columbia, [3]Department of Ophthalmology and Visual Sciences, University of British Columbia

A popular view of the human visual system is that it comprises at least two somewhat parallel pathways: the ventral stream for form and colour, and the dorsal stream for motion. There is also support for a modified view in which slow speeds of motion are processed ventrally. We recently reported speed-tuned psychophysical differences in the typical and atypical development (due to amblyopia) of global motion and motion-defined form perception (Hayward et al., 2011; Narasimhan & Giaschi, 2012). Specifically, immaturities and deficits were reported for slow but not fast speeds. These different developmental patterns may reflect different cortical systems mediating slow and fast motion perception. The current study used functional MRI in adults with normal vision to examine the neural correlates of our psychophysical tasks. The tasks included global motion direction discrimination and motion-defined rectangle orientation discrimination, each at slow (0.1 deg/s) and fast (5 deg/s) speeds. Stimuli were random-walk dot fields presented using a block design with four conditions: high motion coherence, low motion coherence, 0% motion coherence and stationary dots. Coherence levels were adjusted to match the difficulty level across speeds. We examined each task using a whole-brain voxelwise analysis and a 2 (Speed: Fast, Slow) x 3 (Coherence: High, Low, 0%) within-subjects ANOVA. For both tasks, there were significant main effects of Speed and Coherence, and no interaction between the two. On the global motion task, pairwise comparisons between fast and slow speeds showed activation in occipital and parietal regions, with stronger dorsal activation for fast speeds. On the motion-defined form task, comparisons showed activation in occipital regions, with stronger activation in ventral occipital areas for slow speeds. These results demonstrate differences in the cortical systems activated by fast and slow motion, and suggest a role for the ventral stream in the processing of slow speeds.

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26.431 **Decoding pattern motion information in V1** Bianca van Kemenade[1](biancavankemenade@gmail.com), Kiley Seymour[2], Marcus Rothkirch[2], Philipp Sterzer[2]; [1]1Berlin School of Mind and Brain, Humboldt Universität zu Berlin, Germany, [2]Department of Psychiatry and Psychotherapy, Campus Charite Mitte, Charité-Universitätsmedizin Berlin, 10117 Berlin, Germany

Two superimposed gratings moving in different directions can be perceived bound together in a pattern, moving in the average direction of the two gratings. This is referred to as pattern motion. It has been proposed that V1 processes the motion of the components, whereas pattern motion would be processed at higher levels of the visual hierarchy, especially in hMT+/V5. Using multivariate pattern analysis we investigated whether pattern motion is processed as early as in V1. We used stimuli composed of sinusoidal gratings, perceived as patterns, of which the angle between the gratings ranged from 30° to 120°. Two different pattern directions were used. Participants were presented with these stimuli in a pseudo-randomised block design, during which they had to perform a fixation task and a speed discrimination task. Eye tracking was performed to ensure proper fixation. Polar angle retinotopic mapping and a standard functional hMT+/V5 localiser were used to define ROIs. A classifier was trained to discriminate the two pattern directions. The classifier was able to decode the two pattern directions significantly above chance in all ROIs. Cross-classification was performed by training the classifier on a stimulus pair with a certain angle between the gratings, and testing the classifier on another stimulus pair with a different angle. Again, decoding accuracies were significantly above chance, and no significant differences between any of the performed cross-classifications were found in any of the ROIs including V1. This suggests the classifier did not use component motion signals, but more likely pattern motion

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information. Our results indicate that V1 contains pattern motion information. Whether this information is due to genuine pattern motion processing in V1 or to feedback from higher areas remains to be investigated.

26.432 MT Motion integration can be explained by the spatio-temporal frequency content of V1 surround suppression

Maria-Jose Escobar[1](mariajose.escobar@usm.cl), Pedro F. Toledo[1], Guillaume S. Masson[2], Pierre Kornprobst[3]; [1]Universidad Técnica Federico Santa María, Department of Electronics Engineering, Valparaíso, Chile, [2]Team InViBe, Institut de Neurosciences de la Timone, Marseille, France, [3]Neuromathcomp Project Team, Inria Sophia Antipolis, France

Hidden formatting deleted. Delete this text! inter-ideograph">Most of the complex properties computed by high-order layers can be explained by the properties of their inputs: For example, MT response depends on the organization of V1 surround suppression [1]. More precisely, it was shown that the spatiotemporal frequency (STF) content of V1 surround has a similar but broader bandwidth than the classical receptive field (CRF), with a spatial frequency (SF) smaller than the CRF [2,3]. Interestingly, the recent study of [4] showed that higher SFs increase the strength of the surround suppression instead of decreasing it, thus interrogating the classical view of surround configuration. Hidden formatting deleted. Delete this text! inter-ideograph">In this work, we investigate through simulations the role of the STF content of suppressive V1 surrounds to reproduce desired MT population responses. To do so, we propose a V1-MT feedforward model. V1 neurons are implemented as entities defined by STF and orientation selectivity (9 STF, 36 orientations). Suppressive surround is spatially isotropic and it only depends on its STF content given by neighboring V1 neurons. Then, MT neurons response is classically obtained by pooling the activity of V1 neurons in the spatial and orientation domains (8 orientations). The connection weights of the neighboring V1 neurons are learned using a genetic algorithm in order to obtain an expected response at the level of MT. Hidden formatting deleted. Delete this text! inter-ideograph">The system was tested using a plaid type II where the expected MT response is the IOC, and with plaids type I where pattern or component responses are expected in MT. From these simulations, the results show that a variety of population response at the level of MT can be explained by the STF surround suppression at the level of V1.

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26.433 Motion-sensitive area MT+ reflects learning of implied motion in abstract paintings

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Background: A work in our group showed that the neural machinery ordinarily engaged during perception of real visual motion is activated when people view paintings explicitly designed to convey a sense of visual motion (Kim& Blake, 2007). The involvement of the motion sensitive area MT+, however, was specific to people who have prior experience with those paintings. In the present study using fMRI, we investigated whether MT+ shows functional plasticity following learning of implied motion in abstract paintings. Methods: Fourteen observers with little interest in art participated in the study, which consisted of 3 stages including 1) pre-learning scanning, 2) learning, and 3) post-learning scanning. The pre-learning scanning was composed of two MT+ localizer runs and six rapid event-related runs. In each event-related run, nine types of events (four paintings intended to portray motion (MP), four "static" paintings (SP), and a fixation baseline) were repeated nine times and presented in a pseudo-randomized order. During learning stage after a week from pre-learning scanning, observers were given information about 2 MP and 2 SP, randomly selected from 4 MP and 4 SP presented during the pre-learning scanning. The post- learning scanning was identical to the pre-learning scanning. Results: Bilateral MT+ regions were identified successfully in all fourteen observers. In pre-learning results, MT+ responses to MP and to SP were not different statistically. In contrast, post-learning results showed that MT+ activation was greater in response to MP relative to SP. The change of MT+ responses to the two types of paintings before and after learning was not confined to those "learned" paintings but extended to those "not learned" paintings. Conclusion: The neural machinery ordinarily engaged during perception of real visual motion reflects learning of implied motion in abstract paintings intended by artists.

Acknowledgement: This work was supported by the National Research Foundation of Korea Grant funded by the Korean Government (NRF-327-2011-1-B00981)

26.434 Facilitation of rapid motion perception by a static, but not dynamic, synchronous surround

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Because our retinal images are continuously changing, we often have only short time to accurately perceive a new stimulus. It is still unclear how we overcome this problem. For motion perception, we recently showed that temporal synchrony between a moving stimulus and a static reference is important for rapid and accurate perception. Specifically, we found that only for short stimulus presentation, the coherence-signal necessary to discriminate motion in a dynamic random-dot field was halved when a static surround composed of static dots was presented in synchrony with the random-dots (Linares, Motoyoshi & Nishida, 2012). From one perspective, this surround facilitation is counterintuitive. A transient surround adds motion energy in all directions, which, if integrated with the dynamic random-dot field in the center, would reduce the signal to noise ratio, and decrease motion sensitivity. Since the surround instead increases motion sensitivity, the surround might be somehow segmented from center, rather than integrated with it. Segmentation might be based on the difference in temporal structure between the static surround and the dynamic center. If so, adding dynamic dots in the surround should impair rather than facilitate motion sensitivity. From a different perspective, one could consider that the additional energy of the surround could facilitate motion perception due to an accelerating non-linearity of the underlying neural response. According to this view, adding dynamic dots in the surround should facilitate motion perception. We found that a synchronous surround composed of dynamic dots impairs rather than facilitate motion sensitivity in agreement with the first prediction. This finding suggests that center-surround mechanisms integrate the signal of elements sharing temporal structure, while segment and enhance the signal of elements with different temporal structure. In another experiment, we found that the signal enhancement by a static synchronous surround also improves minimum motion detection.

26.435 Noise improves sensitivity during optimized decision-making.

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Perception of visual features is thought to arise from noisy population codes in the brain. For most tasks, not all members of a population are equally suited to the task at hand. For example, for fine discrimination, the most informative neurons are those that have the steepest part of their tuning curve on the decision-boundary. Choice probability analysis suggests that primates assign higher weights to these maximally informative neurons to optimize decision-making. Under more natural conditions, however, such optimization could be difficult because tuning curves (and their derivatives) depend critically on the stimulus set used for their definition. Accordingly, sub-optimal inference is inevitable for real-world perceptual decision-making. We examined effects of optimal and sub-optimal inference on discrimination using a combination of computational modeling and psychophysics in humans and monkeys. We simulated a population of direction-selective neurons and mapped tuning curves for translational motion in random dot patterns. Even though model parameters were fixed, empirical tuning widths could be adjusted (and therefore, which neurons were the most informative) by varying the width of the distribution from which dot-directions were drawn ("external noise"). Discrimination thresholds were measured at different levels of external noise and with two different states of optimization. When optimized for narrow-distribution ("clean") stimuli, thresholds increased monotonically with external noise. When optimized for broad-distribution ("noisy") stimuli, however, thresholds for moderate levels of external noise were actually lower than those for low levels of external noise – even though the latter objectively carried more information about direction. We confirmed this unexpected result psychophysically in humans and monkeys using comparable methods (the two optimization-states were encouraged by presenting different proportions of high and low external-noise trials across blocks). Our results suggest that the visual system can optimize decision-making for expected noisy stimuli at the expense of reduced sensitivity to unexpected high-fidelity signals.

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26.436 Measuring the spatiotemporal contrast sensitivity function in the macaque monkey

Ambarish Pawar[1](ambarish@salk.edu), Paul Laddis[1], Sergei Gepshtein [1], Thomas Albright[1]; [1]The Salk Institute for Biological Studies

The spatiotemporal contrast sensitivity function is a large-scale characteristic of visual performance measured by estimating contrast thresholds across a broad range of spatial and temporal frequencies of luminance modulation (Kelly, 1979; Nakayama, 1985). Estimation of the sensitivity function is important for basic vision research and for evaluating the deficiencies that accompany visual pathology (e.g., Comerford, 1983). The human sensitivity function was previously found to have an invariant shape across tasks and subjects, as predicted by a theory of visual sensitivity (Gepshtein et al., 2007). Changes in statistics of stimulation caused a shift of the sensitivity function in the graph of spatial and temporal frequencies of luminance modulation, while preserving the shape of the function (Gepshtein et al., 2009). How is the large-scale change of sensitivity is mediated by cortical visual neurons, each of which is selective to a narrow range of spatiotemporal stimulation? To answer this question, one needs to evaluate both the behavioral sensitivity function and the sensitivity functions of individual neurons rapidly enough to capture the adaptive transformation of sensitivity. We measured the spatiotemporal contrast sensitivity function in two macaque monkeys, using intensive psychometric procedures that allowed us to estimate contrast thresholds using a fraction of trials required by the method of constant stimuli. In a direction discrimination task, stimulus contrasts were controlled by adaptive Bayesian procedures (Kontsevich and Tyler, 1999; Lesmes et al., 2010) such as to directly estimate parameters of the sensitivity function, rather than the sensitivities for individual stimuli, over a broad range of stimulus conditions (0.05-20 cycles/deg and 0.4-55 Hz). In both monkeys, the sensitivity functions had the same shapes as the human sensitivity function. We validated the results using the method of constant stimuli, indicating that the intensive psychometric procedures could be used to capture adaptive changes of behavioral and neuronal contrast sensitivities.

Acknowledgement: NIH EY018613

26.437 **Spatial specificity of direction selectivity in the dorsolateral prefrontal cortex during memory-guided direction comparison task** Ping Ren[1](greenrpg@hotmail.com), Avi Ben-Simon[1], Bingqing Wang[1], Phillip Spinelli[1], Tatiana Pasternak[1]; [1]Dept of Neurobiology & Anatomy, University of Rochester

As we interact with our environment, the features of objects in the visual scene are not consistently present on the retina and sensory cues used to guide visual behavior are not always available. Thus, active observers are faced with a ubiquitous task of comparing sensory stimuli across time and space. When monkeys compare the direction of motion of two foveally presented stimuli, S1 and S2, separated by a delay, neurons in the dorsolateral prefrontal cortex (DLPFC) show direction selective (DS) responses suggestive of their origins in area MT (Zaksas & Pasternak, 2006). Furthermore, responses to S2 are often modulated by the preceding direction, reflecting the process of sensory comparison (Hussar & Pasternak, 2012). However, DLPFC neurons respond to motion not only at the fovea but also across the entire visual field, receiving direct bottom-up inputs from ipsilateral MT representing contralateral stimuli and indirectly from the opposite MT representing ipsilateral stimuli. Since MT is highly retinotopic, we examined whether DS in DLPFC retains the spatial specificity of its inputs by presenting stimuli in the contralateral and ipsilateral hemifields during the direction comparison task. We found that DLPFC responses often showed large differences in DS for stimuli presented at different visual field locations and these differences were preserved on trials with S1 and S2 appearing in opposite hemifields. This demonstrates that these responses may reflect the convergence of MT inputs representing different spatial locations. We also found that the comparison effects during S2 appeared only when both S1 and S2 were placed in the contralateral hemifield, suggesting that the direct input from ipsilateral MT may be necessary for producing comparison effects in DLPFC. These results demonstrate that the topography of sensory representation in DLPFC is governed by its connectivity with MT.

Acknowledgement: R01 EY 11749 P30 EY01319

26.438 **Rapid loss of information about motion direction but not about its location during memory- guided comparison tasks** Philip Spinelli[1](pspinelli@cvs.rochester.edu), Bingqing Wang[1], Tatiana Pasternak[1]; [1]Dept of Neurobiology & Anatomy, Center for Visual Science, University of Rochester

In everyday perceptual experience stimulus features and their locations are largely inseparable. Indeed, during memory for motion tasks the information about location is preserved along with motion direction (Zaksas et al, 2001; Ong et al, 2009). Despite the documented link between processes underlying retention of features and their locations, little is known about the mechanisms underlying this link. We recently developed a behavioral paradigm that allows direct comparison between the ability to retain motion direction and its location. In the memory for direction task, subjects compare two moving stimuli, S1 and S2, separated by a memory delay and report whether they move in the same or in different directions. In the memory for location task, the two stimuli appear at the same or at different locations and subjects report whether the two locations are the same or different. In both tasks, the precision with which the information is retained is measured by varying the difference between S1 and S2. We trained a monkey on the two tasks and directly compared difference thresholds for direction and location. Both types of thresholds were measured with a 3o moving random-dot stimuli (10o/s) presented at the same eccentricity (7o) over a range of delays separating S1 and S2 (0.75-3sec). The data revealed striking differences in the ability to retain the two types of information, with memory for location persisting with little or no deterioration and memory for direction decaying much more rapidly (tau=2.5s). These results suggest that the two types of information are likely to be mediated and maintained by different neuronal mechanisms, the notion supported by the difference in the nature of delay activity recorded in the prefrontal cortex during memory for location tasks (Funahashi et al, 1989) and during tasks requiring memory for motion (Hussar & Pasternak, 2012).

Acknowledgement: R01 EY11749 P30 EY01319

Motion: Local, adaptation

Saturday, May 11, 2:45 - 6:45 pm

Poster Session, Orchid Ballroom

26.439 **A meridional anisotropy of the flash-drag effect** Anna A. Kosovicheva[1](anko@berkeley.edu), David Whitney[1]; [1]Department of Psychology, University of California, Berkeley

To effectively compare the positions of objects, especially those in dynamic scenes, the visual system may need to construct a representation of space between the objects. How does the visual system construct a representation of space between objects when they are in different visual hemifields? As input from the left and right visual fields is predominantly processed in different hemispheres, we might expect considerable differences in perceived position when the locations of objects are compared within a visual hemifield than when a comparison is made between the left and right hemifields. We tested this hypothesis using the flash-drag effect (FDE). Previous work has shown that when a briefly flashed stationary stimulus is presented near a moving object, the perceived location of the stationary stimulus is biased in the direction of motion following the flash (Whitney & Cavanagh, 2000). On each trial, subjects viewed two adjacent rectangular textured patterns (one each in the left and right visual field) moving in opposite directions (up or down), reversing direction after 380 ms. Two brief stationary flashes were presented superimposed on the moving patterns straddling the vertical meridian at the moment of the motion reversals. Subjects indicated the direction of vernier misalignment in a 2AFC task. Subjects' responses were consistent with a large FDE, such that the perceived vernier misalignment was in the direction of motion following the flash. When the same displays were rotated 90 degrees such that the stationary flashes straddled the horizontal meridian, the FDE was reduced for all subjects, ($p < .05$). The visual system evidently constructs a representation of space between objects in such a way that the space is more easily distorted across the vertical than the horizontal meridian, thus revealing the challenge of reconciling relative position assignment across the hemispheres.

26.440 **Spatio-temporal characteristics of classical apparent motion traversing vertical- and horizontal meridians** Takao Sato[1](L-sato@mail.ecc.u-tokyo.ac.jp), Hidetoshi Kanaya[1], Maata Fujita[1]; [1]Department of Psychology, Graduate School of Humanities and Socioloty, University of Tokyo

Classical or long-range apparent motion is sometimes considered as a first-order motion (Cavanagh & Mather, 1989), but sometimes as an attention-based phenomenon (Horowitz & Treisman, 1994). This confusion partly resulted from the lack of detailed knowledge about spatio-temporal characteristics of classical apparent motion. Thus, in this study, we investigated its spatio-temporal characteristics especially with respect to horizontal and vertical meridians. The stimulus consisted of two white discs (3.8-deg diameter) successively presented against dark gray background. Combinations of motion-directions (vertical/horizontal) and within/across hemifields (right/left or upper/lower) resulted in four conditions. All motions were presented along the horizontal or vertical meridian near the fixation point. The spatial distance was varied in 3 to 6 steps depending on the condition between 15 and 135 deg. The duration was 33ms for all stimuli, and ISI was varied between 0 to 533ms in 7 steps. The observer's task was to judge whether motion was perceived. For within-hemifield motions, motion was perceived nearly 100% from 0 to 300ms ISIs and declined beyond this point regardless of spatial distances and motion directions. These results might suggest that these motions are mediated by local-motion detectors, but it should be noted that the larg-

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est distance here was 60 deg, much larger than ordinary receptive-field sizes. As for inter-hemifield motions, the percentage declines at shorter ISIs and it peaked around 100ms for all stimuli except for the smallest distance where no decline on the shorter side was acknowledged. In summary, these results suggest that classical/long-range apparent motion is mediated by at least two separate mechanisms; most likely a first-order-like mechanism for within-stimuli, and an attention-based mechanism, or another passive mechanism that is susceptible to ISI for across-stimuli. In addition, it is quite intriguing that almost identical inter-hemifield effects were found for upper/lower as well as right/left hemifield.

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26.441 **Segregating Stimulus Information for Counterchange and Motion Energy Determined Motion Perception** Matthew Seifert[1](m-seifer3@fau.edu), Howard Hock[1,2]; [1]Department of Psychology, Charles E. Schmidt College of Science, Florida Atlantic University, [2]Center for Complex Systems and Brain Sciences, Charles E. Schmidt College of Science, Florida Atlantic University

It has been argued that the perception of apparent motion between two spatial locations is based on the detection of counterchange (i.e., oppositely signed changes in contrast at the two locations) rather than motion energy (Hock, Gilroy & Harnett, 2002; Gilroy & Hock, 2005; Hock, Schöner & Gilroy, 2009). A constraint in furthering this distinction is that both counterchange and motion energy are present for most motion stimuli. The results of two experiments are based on specially designed stimuli for which the two kinds of motion-specifying information are segregated. Method Experiment 1 isolated the detection of counterchange. The perception of subjective squares moving across a sequence of four locations was created by pac-men at the corners of the squares, which rotated into and out of alignment over a succession of frames. Motion energy was not a factor because it was limited to the local rotation of the pac-men, which occurred during every frame and at every location, regardless of whether or not subjective squares were formed. Experiment 2 isolated the detection of motion energy. The perception of spreading luminance motion was created by luminance increments occurring sequentially across four simultaneously visible squares. Counterchange was not a factor because the luminance increments always created same-signed changes in contrast. Results: Counterchange-specified motion was perceived for a wide range of frame durations, and was stronger when the subjective squares were perceived moving across smaller distances. Motion energy specified motion was preferentially perceived for brief frame durations (fast speeds). It was not stronger when the squares were closer together. If anything, motion perception tended to improve when the squares were perceived moving across greater distances, the inverse of the results for counterchange detection. Conclusions: Counterchange and motion energy mechanisms for the perception of apparent motion differ in both their temporal and spatial sensitivity.

26.442 **Aging does not decrease spatial suppression in a motion step task** Lindsay E. Rosen[1](farberle@mcmaster.ca), Allison B. Sekuler[1,2], Patrick J. Bennett[1,2]; [1]McMaster Integrative Neuroscience Discovery & Study (MiNDS) Program, McMaster University, [2]Department of Psychology, Neuroscience & Behaviour, McMaster University, [3]Centre for Vision Research, York University

Direction discrimination becomes more difficult as high-contrast stimuli increase in size and as low-contrast stimuli decrease in size (Tadin et al., Nature, 2003). However, although older adults show spatial summation at low contrast, they demonstrate no evidence for spatial suppression at high contrast (Betts et al., Neuron, 2005). It has been hypothesized that this behavioural finding occurs as a result of decreased GABAergic inhibition in the aging visual system (Leventhal et al., Science, 2003), but it is unclear whether the finding extends to other tasks; for example, static tasks have not shown the same effects of aging (Karas & McKendrick, J Vis, 2009; Farber et al., VSS 2010 & 2011). Recently, Churan et al. (J Vis, 2009) described results from a motion step task consistent with summation at low contrast and suppression at high contrast for younger subjects, providing us with an opportunity to examine the effects of aging in another paradigm using brief motion stimuli. In the current study, we tested six younger and four older adults in this task. A vertically-oriented 0.5 cpd Gabor stimulus remained static in the center of the screen for 35 ms, and then, after a brief motion step, the phase-shifted gabor was presented for another 35 ms. A 2-down, 1-up staircase manipulated the size of the phase jump (1-89 deg) required to correctly determine the motion direction. There were four blocks, one for each combination of contrast (1.5, 98%) and size (4.56, 17.68 deg). Results from younger subjects replicated the findings from Churan et al. (2009), and older adults also demonstrated this pattern of spatial summation at low contrast and spatial suppression at high contrast. Hence, we found no evidence of an age-related reduction in spatial suppression in this task, suggesting that the phenomenon may be limited even for brief motion stimuli.

Acknowledgement: OGS

26.443 **Cross-modal motion-induced position shift** Hsin-Hung Li[1](hsinhungli@gmail.com), Won Mok Shim[1], Patrick Cavanagh[1]; [1]Department of Psychological and Brain Sciences, Dartmouth College

When a flashed target is presented close to a moving texture, the perceived position of the target is shifted in the direction of the motion following the flash (Whitney and Cavanagh, 2000). This effect is strongest when the target is superimposed on the motion and presented when the motion reverses direction (Anstis & Cavanagh, VSS 2011). Here we investigated whether visual motion can shift the perceived position of an auditory target and compared it to the shift induced in a visual target. A 32° x 22° field of white random dots moved horizontally at 40 degrees per second, reversing direction every 1500 ms. A burst of white noise was presented on two loudspeakers on the left and right of the monitor at the same time that the motion reversed direction. The apparent location of the noise burst was varied between approximately -16° and +16° from screen center by changing the inter-speaker delay. Six observers reported whether the sound was located to the left or right of screen center. We also tested the effect of the random dot motion on a visual target flashed synchronously with the motion reversal. For the visual target, consistent with previous literature, the perceived position of the flash was significantly shifted in the direction of the motion following the flash. However, for the auditory target there was no overall shift: 3 observers showed a null effect whereas the remaining 3 observers reported a significant shift of the auditory target in the direction opposite that was seen for the visual target (corrected for multiple independent tests). The difference between the direction of visual and auditory shifts was marginally significant. These results suggest that the effect of motion-induced position shift may operate differently in crossmodal space.

26.444 **Orientation dependency of motion masking relative to the direction of apparent motion** Yuki Murai[1](ymurai.cbs13@gmail.com), Ikuya Murakami[1]; [1]Department of Life Sciences, The University of Tokyo

A target presented along the trajectory of two-dot apparent motion (AM) is less visible. This phenomenon of motion masking implies that the mental representation of AM can interfere with processing of other sensory inputs. Motion masking was first introduced as suppression of higher processing such as letter identification (Yantis & Nakayama, 1998), but recently, masking has been reported to increase when the difference in orientation between the AM stimuli and the target decreases and thus has been discussed in relation to suppression at an early stage (Hidaka et al., 2011). Our study aims to examine whether motion masking is based only on the similarity in physical attributes between the AM stimuli and the target or whether the AM direction plays some role. We used a random-noise luminance carrier confined within a Gaussian contrast window as each element of the two-dot AM stimuli, and a Gabor patch as the target. In each trial, two vertically or horizontally aligned elements of the AM stimuli were flashed asynchronously, and the target was either flashed between the two elements or absent. Target detectability was measured against Gabor orientation. If masking was based only on the stimulus similarity, orientation dependency should not be observed because random noise has no predominant orientation. Surprisingly, we observed orientation dependency of detectability associated with the perceived direction of AM. When the AM stimuli appeared to move horizontally, a horizontal patch became less detectable than a vertical patch. When the AM stimuli appeared to move vertically, the vertical patch became less detectable. These results were also confirmed when plaid stimuli were used as the elements of the AM stimuli. To reconcile apparent controversy between our findings and previous notions, multiple levels of object processing and differences in task strategy are discussed in relation to the identification of overlapping objects.

26.445 **Influences of local and global motion on perceived position** Peter J. Kohler[1](peter.kohler@dartmouth.edu), Leif H. Harder[1], Peter U. Tse[1]; [1]Psychological and Brain Sciences, Dartmouth College, Hanover, NH

The perceived position of a briefly flashed stimulus can be shifted in the direction of nearby motion (Whitney & Cavanagh, 2000). We used a horizontally translating diamond stimulus (Lorenceau & Shriffrar, 1992) to examine how different global motion interpretations of ambiguous local motion affect motion-induced position shifts. Two dots were flashed as motion direction reversed, such that the dots appeared shifted in opposite directions. Subjects adjusted comparison stimuli to report perceived dot positions. We found that the perceived motion direction influenced the direction of the position shift, even when the overall motion in the image

Saturday PM

was kept constant. Surprisingly, although the effect of global motion was highly significant, the shift direction did not completely follow the motion direction: Even when the global motion percept was clearly vertical or horizontal, the shift was far from aligned with the motion direction. Others have found that high-level motion can cause position shifts in the absence of any local motion signal (Shim & Cavanagh, 2004), but our results suggest that there can be local, as well as global, contributions to motion-induced position shifts. We are currently conducting a second set of experiments, to further investigate the contributions of local and global motion to the position shifts. Motion integration takes place over a ~150ms period (Pack & Born, 2001), and by modulating the dot timing relative to motion transients, we can allow motion integration to finish before the dot is presented. This allows us to determine if the local motion contribution to the shift occurs because motion has not yet been fully integrated at the time of the dot presentation, or if there are inherent local contributions to motion-induced position shifts. Determining the contributions of local and global motion to motion-induced position shifts is an important step towards understanding the neural mechanisms underlying the phenomenon.

26.446 **The orientation tuning of motion streak mechanisms revealed by masking.** David Heslip[1](lpxdh1@nottingham.ac.uk), Timothy Ledgeway[1], Paul McGraw[1]; [1]School of Psychology, University of Nottingham.

It has been suggested that whenever an object moves the successive changes in position over time generate a 'motion streak' that can activate local orientation-selective neurons aligned along the axis of motion. These streaks could help resolve the inherent directional ambiguity (aperture problem) of local motion sensors that respond to moving objects. Indeed Geisler (1999; Nature 400: 65 69) showed that 1-D spatial noise masks parallel to a moving object's trajectory elevate detection thresholds more than orthogonally-oriented noise masks. We sought to systematically quantify the orientation tuning and bandwidth of this masking phenomenon. In a 2IFC motion-detection task observers (N=4) identified which of two intervals (450ms each), containing spatially 1-D dynamic noise (0.1 contrast), contained a superimposed moving Gaussian blob (SD 0.067°). Contrast detection thresholds (75% correct) for the blob were measured using the method of constant stimuli for each of a range of 7 mask orientations (0 to 90° relative to the motion axis). Performance was measured at speeds of 5.4 and 10.6°/s. In agreement with previous studies, observers' thresholds were ~ 20% higher when the noise mask was orientated parallel to the motion axis (0°) than when it was orthogonal (90°). However the threshold versus mask orientation function was found to be non-monotonic in that peak masking typically occurred 5 to 10° away from the axis of motion. Testing with different motion directions showed that this phenomenon was not an oblique effect due to an anisotropy in orientation encoding. Additionally the tuning of the masking function was broader at the slower object speed. These results are not readily explicable in terms of current models of motion streak encoding and place important constraints on the nature of the putative interactions between local orientation detectors and motion mechanisms in human vision.
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26.447 **Local motion-contrast Interactions Influence Global Shape Perception** Gennadiy Gurariy[1](genaxl@yahoo.com), Gideon Caplovitz[1]; [1]Psychology, University of Nevada, Reno

The perception of objects in the world depends upon the successful integration of form and motion into a unified neural representation and has traditionally been thought to occur through separate pathways. However, it has recently been shown that that these processes may interact in complex ways. The perceived global shape of an object is dictated by the spatial relationships of its local constituents and can be influenced by physical speed. Recent work has demonstrated that shape distortions can be perceived even when speed is held constant. For example, the perceived speed of local constituents was shown to be influenced by their orientation relative to their direction of motion and subsequently led to global shape distortions. Here, we investigate whether other local modifications, specifically luminance contrast, can alter perceived speed and also influence global shape. It has been previously demonstrated that the subjective perception of an object's velocity slows down as a function of reduced contrast. Utilizing the method of constant stimuli, we presented stimuli consisting of four Gaussian blobs arranged to form the corners of a rectangle which varied across different aspect ratios and traversed either the vertical or horizontal axis. Participants were asked to make a judgment concerning the orientation of the rectangle as being vertical or horizontal. If perceived speed influences global shape then we would predict global extension or compression from lowering the contrast in trailing or leading edge blobs, respectively. Our results were consistent with this hypothesis, specifically, the leading edge blobs with reduced contrast appeared to move slower resulting in the global shape appearing more compressed relative to either lowered contrast trailing edge or full contrast conditions. In conclusion, our study supports the hypothesis that form and motion are not disjoined and that perceived speed can be contingent upon the local degree of contrast.

26.448 **Effects of spatial attention on motion aftereffects.** Wendy J Adams[1](w.adams@soton.ac.uk), Tomas HJ Knapen[2], Erich W Graf[1], Jan W Brascamp[2,3]; [1] Psychology, University of Southampton, [2]Psychology Department, Cognitive Neuroscience Group, University of Amsterdam, [3]Helmholtz Institute, Division of Experimental Psychology, Utrecht University

We addressed two questions relating to motion and attention: Firstly, is motion adaptation greater when attention is directed toward a peripheral adaptation stimulus, rather than directed to a central, motion-irrelevant stimulus? Secondly, is attention required to produce colour-contingent motion aftereffects (MAEs)? Although attention has previously been found to boost the MAE (e.g. Chaudhuri, 1990; Taya, Adams, Graf & Lavie, 2009; Kaunitz, Fracasso & Melcher, 2011), the validity of these findings has recently been questioned (Morgan, 2011, 2012). Additionally, recent work suggests that when motion and colour are misbound to produce an illusory colour-motion conjunction (as in Wu, Kanai & Shimojo, 2004) the resultant colour-contingent MAE depends on the perceived, rather than the actual contingency (Zhang & Fang, 2012, although see Blaser, Papathomas & Vidnyánszky, 2005). This result suggests that colour-motion binding may not be early and automatic, and may thus depend on attention. In the present study, observers viewed an annulus of isoluminant red and / or blue dots that moved coherently to produce clockwise or anti-clockwise motion. While this adaptation stimulus was present, observers either: (i) counted brief periods of increased motion speed, or (ii) counted light vowels amongst a stream of centrally presented light and dark letters. The difficulty of these two tasks was modulated online to maintain 75% correct performance. The resultant MAEs were quantified with test stimuli composed of red or blue dots using a nulling, staircase procedure. In agreement with previous reports, directing spatial attention to the peripheral motion stimulus increased the MAE. However, colour-contingent MAEs were observed in both the motion and letter task conditions, supporting the notion that binding of colour and motion occurs automatically.

26.449 **Biological Motion Sex Aftereffects Are A Result Of Low-Level Adaptation** Eric Hiris[1](ejhiris@smcm.edu), Michelle Klima[1], Ryan Thompson[1]; [1]Psychology Department, St. Mary's College of Maryland

Past research has shown that adaptation to point-light walkers (PLWs) creates sex aftereffects; for example, adapting to a female PLW biases subsequently viewed PLWs to be perceived as male. In two experiments, we sought to determine whether sex aftereffects are created at a high-level in the visual system where neurons are size, location, and view invariant or at a low-level where neurons are size, location, and view dependent. In two experiments, observers adapted to exaggerated male, neutral, or exaggerated female PLWs for 8 seconds and were tested on PLWs that ranged from slightly male to slightly female for 1 second. In Experiment 1, observers adapted either to a frontal (0°) or side (90°) view of a PLW followed by a 0°, 45°, or 90° test PLW. A biological motion sex aftereffect was found for the 0° adapting stimulus when the test stimulus was 0° (strong aftereffect) or 45° (weak aftereffect). No aftereffects were observed in any of the other conditions. These results suggest that the biological motion aftereffect is view-dependent, indicating that the adaptation creating this aftereffect is at a low-level in the visual system. The lack of an aftereffect when the adaptation stimulus was 90° may be the result of sex information being more difficult to perceive in side views. In Experiment 2, observers adapted either to a small (8° in height) or large (16° in height) PLW and then viewed either a small or large test PLW. A biological motion sex aftereffect was found only when the adapting and test size matched. These results show that the biological motion aftereffect is size-dependent, indicating that the adaptation creating this aftereffect is at a low-level in the visual system. Together these experiments provide strong evidence that the biological motion sex aftereffect is based on low-level, not high-level, adaptation.

26.450 **MIB as an adaptation phenomenon: evidence from the motion aftereffect** Erika Wells[1](wellse@union.edu), Andrew Leber[2]; [1]Department of Psychology, Union College, [2]Department of Psychology, Ohio State University

Motion-induced blindness (MIB) is an illusion in which peripheral targets perceptually disappear when surrounded by a moving mask (Bonneh et al., 2001). It has recently been proposed that disappearance results from a competition biased towards the transient mask due to stronger sensory adaptation of the stationary target (Gorea et al., 2009). Evidence supporting this adaptation account has primarily emerged from reports of MIB's

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increasing magnitude across the trial (Gorea et al. 2009; Wells et al., 2011). However, timecourse effects could be due to changes in attentional or decisional processes over time rather than adaptation. Thus, our goal in the present study was to develop a novel method to test the role of adaptation in MIB. Specifically, we employed the motion aftereffect (MAE) as a measure of adaptation to the moving mask to determine whether motion adaptation could be linked to the reported amount of MIB. The adaptation account predicts that trials with more mask adaptation, or MAE, would yield less MIB. Method: The mask was composed of dots moving to the left or right with 100% coherent motion for 30 sec. In Part 1 of each trial, subjects reported the disappearance of a target. In Part 2, subjects' MAE was assessed. The procedure involved estimating the direction and coherence of a 0%, 25%, or 50% coherent motion stimulus moving left or right. Results: We found a clear relationship between the magnitude of MIB and the MAE. Specifically, on trials when MIB was low, MAE was strongest, and on trials when MIB was high, MAE was weakest. These findings are consistent with the notion that greater adaptation to the mask is associated with diminished strength of the mask representation, reducing its competitive advantage over the target, and ultimately decreasing disappearance. These findings add novel support for the adaptation account of MIB.

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26.451 **Linking the neural and perceptual consequences of motion adaptation.** Neil Roach[1](nwr@psychology.nottingham.ac.uk), David McGovern[1], Ben Webb[1]; [1]Visual Neuroscience Group. School of Psychology. The University of Nottingham.

Adaptation is a widespread property of sensory systems, generally defined as any change in processing that follows a change in recent input statistics. In the visual system, the effects of adaptation have been described across a variety of different levels of investigation, ranging from the perceptual judgments made by human observers to the spiking activity of individual neurons. As a consequence, the study of adaptation phenomena provides an important testbed for theories that aim to bridge the gap between perception and its underlying neurophysiological mechanisms. The perceptual consequences of visual motion adaptation are often modeled within a simple population-coding framework in which adaptation selectively alters the responsivity of direction-selective cortical neurons (e.g. reducing the gain or tuning bandwidth of neurons with preferred direction that are similar to the adapting stimulus) and downstream mechanisms tasked with decoding population activity fail to compensate for these changes. Here we examine how successful this approach is in accounting for adaptation-induced biases in perceived motion direction (i.e. direction aftereffects) and changes in direction discriminability. We show that observed patterns of bias are consistent with a large set of neural adaptation parameter values, including (but not limited to) those previously reported in single-unit recording studies. The same parameter sets however, systematically underestimate changes in observers' direction discrimination threshold. Conversely, parameter values that permit an approximation of the profile of changes in discriminability dramatically over-predict the magnitude of shifts in perceived direction. To address this discrepancy, we consider the potential impact of additional factors including the nature of the read-out mechanism and modifications of the pattern and/or correlation structure of neural response variability. Our results suggest that the quantitative relationship between adaptation-induced changes in bias and discriminability places tight constraints on the nature of the underlying neural mechanisms.

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Eye movements: Pursuit

Saturday, May 11, 2:45 - 6:45 pm

Poster Session, Orchid Ballroom

26.452 **Position information improves prediction for pursuit** Amarender Bogadhi[1](amarender.bogadhi@nih.gov), Kurt Debono[2], Alexander Schütz[2]; [1]Laboratory of Sensorimotor Research, National Eye Institute - NIH, [2]Abteilung Allgemeine Psychologie, Justus-Liebig-Universität Gießen

Expectation of target motion is known to result in anticipatory smooth pursuit. Studies investigating prediction for smooth pursuit have often used simple stimuli like a translating dot. A recent study showed that anticipatory smooth pursuit can be triggered by global motion, using random dot kinematograms (RDK). Hence anticipatory pursuit does not require position information about an object moving across space (Santos et al 2012). However, this raises the question if this holds for prediction in general and if position information can improve predictive behavior (Heinen et al 2011,SfN). To investigate this, we used a single dot or a RDK stimulus as a pursuit target moving at 12o/s in a blanking paradigm (Orban de Xivry et al 2006). On target reappearance after the blank, target velocity could be 12o/s or 8o/s or 16o/s. Speed and target conditions were blocked to facilitate prediction on target reappearance. The results showed that the average anticipatory eye velocity at target initiation was 106% higher in blocks with dot stimulus (4.52±0.23o/s) compared to blocks with RDK stimulus (2.19±0.11o/s). Average anticipatory eye velocity at target reappearance after blank was 37% higher for dot stimulus (4.08±0.21o/s) compared to RDK (2.98±0.15o/s). Also, this anticipatory pursuit on target reappearance was scaled to target velocity after blank for the dot, but not for the RDK stimulus. Pursuit and saccadic displacements during blank were negatively correlated for both dot and RDK, with 29% higher saccadic displacement for dot compared to RDK and with similar pursuit displacements for both dot and RDK. These results suggest that position information from an object moving across space is not necessary, but dramatically improves the prediction for pursuit. This improvement is difficult to explain in the framework of gain modulation of eye velocity memory employed in the current models.

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26.453 **Rolling motion makes the eyes roll: torsion during smooth pursuit eye movements** Janick Edinger[1](jedinger@students.mail.uni-mannheim.de), Dinesh Pai[2,3], Miriam Spering[1,3]; [1]Ophthalmology & Visual Sciences, University of British Columbia, [2]Computer Science, University of British Columbia, [3]Brain Research Centre, University of British Columbia

Introduction: We frequently observe horizontal and vertical movements of the eyes, but what is less often noted is the fact that the eye can also rotate about the line of sight, resulting in torsional eye movements. Torsion may serve to compensate for rotations of the head, but its exact function is unclear. Here we examine the functional role of torsion during smooth pursuit eye movements by testing whether torsion can be visually triggered. Methods: Observers (n=8) tracked a random-dot pattern, which moved to the left or right at 10 deg/s, and rotated around its center, either clockwise or counter-clockwise relative to translational motion, at speeds ranging from 151-208 rad/s. In control experiments, we varied stimulus size (4-12 deg) and elevation of gaze. We recorded 3D eye position with a head-mounted Chronos ETD in head-fixed observers. Results: We discovered strong torsion in the direction of stimulus rotation during smooth pursuit. Torsion was fastest in response to natural rotation, the direction an object would rotate if it was rolling on the ground. Natural and unnatural rotation triggered two different patterns of torsion: natural rotation resulted in smooth, continuous torsion at a significantly higher rotational speed than unnatural rotation, which triggered a torsional nystagmus. Natural rotation also produced more accurate pursuit. Torsion increased as a function of stimulus size, but effects were constant across gaze elevations. Conclusion: We provide the first evidence of visually-triggered torsion during pursuit. The torsional strength varied systematically with visual stimulus properties such as direction and size, indicating that torsion could play an important role in stabilizing pursuit during image rotation. Listing's Law, which describes the kinematics of 3D eye movements and predicts zero torsion during pursuit, does not hold here.

26.454 **Transient contrast-induced perceived-velocity perturbations and smooth pursuit: tracking the footstep illusion** Laurent Madelain[1,2](laurent.madelain@univ-lille3.fr), Anna Montagnini[2], Guillaume Masson[2]; [1]Psychology dept., Univ Lille Nord de France , [2]Institut de Neurosciences de la Timone UMR 7289 CNRS & Aix-Marseille Univ

At slow target velocities, there is a linear increase in smooth pursuit eye velocity gain with increasing contrast, a phenomenon which supports the assumption that perceptual and motor responses are driven by a shared signal: low-contrast stimuli consistently appear slower than the same targets presented at higher contrast. The "footstep" illusion is based on these perceived changes in target velocity. Here we ask whether one may use the footstep illusion to probe the effects of transient perceived-velocity perturbations on smooth pursuit in the absence of perturbation in the target's position signal. Three subjects peri-foveally tracked a bright yellow horizontal bar translating over a black-and-white grating. On high luminance trials the translating yellow bar's luminance contrast was 1% and 100% with respect to the white and black stripes respectively, whereas on control trials, the luminance contrast of the stimulus was 50% with respect to all stripes. Luminance contrast varied at 2, 2.5 or 3Hz, depending on the target velocity and on the grating spatial frequency. We found that in the high luminance trials, pursuit velocity gain was oscillating at a frequency locked to the contrast's frequency indicating that eye velocity was well controlled by the local luminance contrast. In a second experiment, the paradigm was identical except that the yellow bar first had a low luminance (50% contrast). At a variable point of time in the trial, the luminance increased for 500 ms (1% and 100% luminance contrast) before returning to the low luminance level. We found a strong transient response in velocity gain when the luminance transiently changed. These results extend previous work on the effects of luminance contrast on smooth pursuit and provide a new tool to selectively and transiently perturb pursuit eye velocity in the absence of perturbation in the target position.

26.455 **Different temporal integration for ocular following and speed perception** Claudio Simoncini[1](claudio.simoncini@univ-amu.fr), Laurent U. Perrinet[1], Anna Montagnini[1], Guillaume S. Masson[1]; [1]Institut de Neuroscience de la Timone, CNRS & Aix Marseille Université

The visual system does not process information instantaneously, but rather integrates over time. Integration occurs both for stationary objects and moving objects, with very similar time constants (Burr, 1981). We measured, as a function of exposure duration, speed discrimination and ocular following performance for rich textured motion stimuli of varying spatial frequency bandwidth. Psychometric sensitivity and Oculometric sensitivity for these patterns increased with exposure duration. However the best stimuli for ocular following (namely those with a large bandwidth for spatial frequency) was well integrated up to about 150 - 200 msec, while the best stimuli for speed discrimination (small bandwidth) was well integrated up to about 300 msec. Interestingly, discriminability of ocular tracking eye movements follow a non-monotonic time course, due to the contribution of motor noise. These results suggest that although perception and action relies works in synergy, they may be described by two different integrating mechanisms: A low level, fast one guiding the ocular movement to enable one to catch stimuli in the visual field quickly; and a slower one being able to measure the speed difference between two objects translating in the visual field. Burr, D.C. (1981). Temporal summation of moving images by the human visual system. Proceedings of Royal Society, B211, 321 - 339

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26.456 **Systematic deviation of eye-movement direction from stimulus-direction during Optokinetic Nystagmus** Andre Kaminiarz[1](andre.kaminiarz@physik.uni-marburg.de), Kathrin Bartelheimer[2], Frank Bremmer[1]; [1]Neurophysics, Philipps-University Marburg, [2]University of Heidelberg

Optokinetic nystagmus (OKN) is a reflexive eye movement, which serves to stabilize the retinal image. It consists of two alternating phases: a slow phase in the direction of stimulus motion and a fast phase in the opposite direction. It is well known that eye-movement characteristics are affected by stimulus direction. During smooth pursuit the eye-movement direction systematically deviates from target direction [oblique effect: Krukowski & Stone, 2005] in a way that can be interpreted as a perceptual expansion of space around the cardinal axes. Based on neurophysiological recordings in macaque monkeys, it had been suggested that the neural basis of this phenomenon is located in area MST or further downstream of the cortical visuo-motor system. Here we investigated in psychophysical experiments in humans whether also slow-phases of stare OKN show an oblique effect. We recorded eye movements from human subjects performing OKN while looking at large random dot patterns moving at 20°/s in 24 directions (0, 15, …, 345°) . Subjects were instructed to watch the stimulus without intentionally following individual dots. All subjects showed a periodic deviation of eye-movement direction from stimulus-direction. Eye-movement patterns revealed three different periodicities: 90°, 180°, and 360°. A 90° period with a phase-shift of 0° resulted in a shift of eye-movement direction away from both cardinal axes as described for smooth pursuit. The 180° error pattern in combination with the observed phase-shifts resulted in a shift away from one of the cardinal axes. The 360° error-pattern induced a shift in a single direction, which was upward for most subjects. Taken together we showed that during voluntary and reflexive eye-movements similar deviations of eye-movement direction from stimulus-direction can be observed. We conclude that the neuronal basis of the effect is located rather early within the cortical visuo-motor system (area MST or upstream).

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26.457 **Attentively segregated moving elements are effortlessly integrated to drive pursuit** Scott Watamaniuk[1](scott.watamaniuk@wright.edu), Zhenlan Jin[2], Elena Potapchuk[2], Stephen Heinen[2]; [1]Department of Psychology, Wright State University, [2]The Smith-Kettlewell Eye Research Institute

Previously, we showed that observers could pursue a multiple-object tracking (MOT) stimulus (Pylyshyn & Storm, 1988) while simultaneously keeping track of a subset of the local elements without cost to either task (Watamaniuk et al., 2009). Moreover, pursuit in this paradigm is guided not by memory, but by constant integration of component motions (Jin et al., 2010). Here we show that the quality of pursuit is dependent upon the number of elements in the stimulus, and further, that the motion signal driving pursuit is integrated across both MOT targets and distractors. The stimulus comprised 4, 8, or 10 dots that moved randomly within a virtual 10x10 deg containment region, and observers attentively tracked 2, 4 or 5 target dots, respectively. During the MOT task, the stimulus either translated from left to right at 7 deg/sec, or remained at the center of the screen without translational motion. In a subset of trials, observers also pursued the stimulus without performing the MOT task. We found that performance on the MOT task was the same with and without pursuit. When the number of MOT targets was increased, performance on the task was poorer, but pursuit gain improved. Pursuit gain was also no different with and without the task, indicating that observers were not pursuing only the targets or only the distractors. The results suggest that motion integration during pursuit is a relatively inattentive process and that attentively tracked elements are not excluded from the integration.

Acknowledgement: NIH #1 1R01EY021286-02

26.458 **Smooth pursuit "go" circuitry is affected by priming, "nogo" circuitry by cognitive expectation** Stephen Heinen[1](heinen@ski.org), Elena Potapchuk[1], Scott Watamaniuk[2]; [1]Smith-Kettlewell Eye Research Institute, [2]Wright State University

Reaction time decreases during target selection if the target appears repeatedly in the same location. This phenomenon is known as priming, and is thought to occur because of a low-level memory of target location. Priming is also evident in anticipatory pursuit. Since both tasks have visual and motor components, it is not clear whether priming occurs in visual or motor pathways. In an attempt to determine this, we employ our go/nogo ocular baseball task in which trials either have visual and motor components, or visual components alone. Observers fixated a central point surrounded by a 4 deg circle (plate). A target moved at 10 deg/sec from the periphery toward the plate. Observers decided whether the target would intersect the plate (strike) or not (ball), and enforced their decision by pursuing the target for strikes, or maintaining fixation for balls. Strikes and balls were randomized. Errors occurred on ball trials preceded by strikes (43% errors), indicating that strikes caused priming. However, strikes preceded by balls were always accurate (0% errors), indicating balls did not prime. We next investigated whether cognitive expectation of rule state (strike or ball) on a given trial could override priming. To do this, the probability of rule state-reversal from trial to trial was varied from 0-100 %. At 0% reversal, rule state remained constant, enabling both cognitive expectation and priming. At 100% reversal, rule state reversed on every trial, enabling cognitive expectation, but opposing the priming effect. We found that strike trials were more subject to priming, but cognitive expectation had a greater effect on ball trials. The results suggest that priming occurs in the go circuitry of the pursuit system, while the nogo circuitry is more susceptible to cognitive influence.

26.459 **Feature-based attention gates motion signals for smooth pursuit** Dirk Kerzel[1](dirk.kerzel@unige.ch), David Souto[1]; [1]Faculté de Psychologie et des Sciences de l'Education, Université de Genève

Attention is necessary for target selection during the initiation and maintenance of smooth pursuit eye movements. We asked whether background motion signals would affect smooth pursuit when they were selected by feature-based attention. Observers pursued a target moving horizontally across a background made up of 40 green and 40 red dots. About 300 ms after target motion onset, the dots moved vertically for 100 ms. One half of the dots moved upwards, while the other half moved downwards. Dots moving in the same direction had the same color. Observers' primary task was to pursue the horizontally moving target. In addition, they were instructed to attend to one half of the dots and to indicate a small change in their direction of motion. Target and distractor dots were randomly placed such that discrimination could not be based on spatial selection. A vertical ocular tracking response occurred in response to the attended dot motion. The amplitude of the attention-based tracking response was 30% of the tracking response elicited in a single task with only one direction of background motion. Across experiments, we varied the predictability of the vertical direction of the to-be-attended dot motion and found that unpredictable dot motion abolished vertical ocular tracking and reduced discrimination performance. Because of the brevity of the motion signal, it may be too difficult to direct feature-based attention to randomly varying directions of motion. We have established that feature-based attention can gate the motion signals that drive smooth pur-

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suit, even when those are irrelevant to the pursuit task. It appears that unlike the effects of spatial attention, the effects of feature-based attention depend on the repeated presentation of the same relevant features.
Acknowledgement: FNS 100014-135374

26.460 Bribing the eye: expected reward modulates smooth pursuit eye movements Aenne Brielmann[1](aenne.brielmann@gmail.com), Miriam Spering[1]; [1]Ophthalmology & Visual Sciences, University of British Columbia, Vancouver, Canada

Introduction: Reward expectancies can have profound effects on behavioral choices: primates select the target that is associated with the highest expected reward or value. Previous studies on smooth pursuit eye movements, the eyes' main response to visual motion, showed that eye velocity dynamically reflects selection in favor of targets with higher expected reward. The current study examined whether reward also modulates basic kinematics of human smooth pursuit: does expecting a higher reward make us track moving objects better? Methods: We recorded eye position in 22 untrained human observers who were instructed to accurately track a small spot of light, moving at constant speed across a computer monitor; luminance contrast of the spot was either high (exp1) or low (exp2). Expected reward was manipulated by using pictures of Canadian 5 or 25 cent coins as cues (presented for 1000 ms preceding stimulus motion) indicating a low or high-reward trial, respectively. The ratio of low- to high-reward trials was 4:1; reward cues were equal in size and luminance. Observers were told that for each high-reward trial 25 cents would be added to their remuneration as a reward for accurate tracking. A control condition without reward cues served as a baseline. Results: We found consistent effects of reward expectation on smooth pursuit in both experiments. In high-reward trials, pursuit was initiated faster (higher acceleration and velocity) and maintained with better accuracy (gain) and lower velocity error. High reward also resulted in smoother pursuit responses with fewer and smaller catch-up saccades. Conclusion: We found adaptive improvements of smooth pursuit as a result of high reward expectation across the entire pursuit response. Reward may increase neuronal sensitivity, thereby boosting the system's capability of processing visual motion information for pursuit.

Face perception: Inversion, eye movements, gaze perception

Saturday, May 11, 2:45 - 6:45 pm

Poster Session, Vista Ballroom

26.501 The Impacts of Inversion and Thatcherisation on Face Processing: Mapping between ERP and GRT Natalie Mestry[1](natalie.mestry@soton.ac.uk), Michael J. Wenger[2], Tamaryn Menneer[1], Nick P. Benikos[1], Nick Donnelly[1]; [1]Psychology, University of Southampton, UK, [2]Department of Psychology, University of Oklahoma

Prior work on the Thatcher illusion (Cornes et al., 2011; Mestry et al., 2012) has indicated both perceptual and decisional components of the illusion. We provide evidence of neural correlates associated with independent influences of inversion and level of feature manipulation (Thatcherisation) in the Thatcher illusion. We also provide an account of how ERP results can be interpreted within the configural processing framework defined by general recognition theory (GRT). We conducted a study examining inversion and the level of Thatcherisation (typical face, eyes Thatcherised, mouth Thatcherised, or both features Thatcherised) on a set of event-related components (the P1, N170, P2 and P3b) that have previously been considered in relation to the Thatcher illusion. Results reveal three independent effects: (1) inversion effects leading to increased amplitude for inverted faces at the N170 and P2 in the occipito-parietal area; (2) a reduction in N170 amplitude with level of Thatcherisation in the right hemisphere; and (3) inversion effects leading to increased amplitude for inverted faces at P3b in the centro-parietal area. This study reveals effects of Thatcherisation that are independent from effects of inversion in the ERP data. These effects can also be mapped to perceptual and decisional measures of configurality revealed in behavioural data using GRT (Mestry et al., 2012). We suggest the Thatcherisation effect at N170 may relate to violations of perceptual independence, the inversion effect across N170 and P2 may relate to violations of perceptual separability, and the inversion effect at P3b may relate to violations of decisional separability. Thus, we suggest a possible role for ERP data in providing a source of converging evidence for inferences regarding the role of perceptual and decisional factors in configurality.
Acknowledgement: ESRC

26.502 Individual differences reveal no disproportionate inversion effect for faces Tirta Susilo[1](bagus.t.susilo@dartmouth.edu), Brad Duchaine[1]; [1]Department of Psychological and Brain Sciences, Dartmouth College

A fundamental hallmark of face perception is the disproportionate face inversion effect: the finding that stimulus inversion disrupts perception of faces more than perception of non-faces (Yin, 1969). This effect is commonly viewed as evidence that perception of upright and inverted faces rely on at least partially distinct mechanisms, whereas perception of upright and inverted non-faces rely on largely similar mechanisms. At the individual differences level, this view predicts that perception of upright and inverted stimuli should correlate less for faces than for non-faces. This prediction was tested in three experiments. In Experiment 1 (n = 82), the upright-inverted correlation is larger for faces (0.71) than for bodies (0.23). In Experiment 2 (n = 90), the upright-inverted correlation is similar for faces (0.30) and for bodies (0.28). In Experiment 3 (n = 72), the upright-inverted correlation is similar for faces (0.56) and for houses (0.56). Contrary to the prediction, we consistently found no evidence of a weaker upright-inverted correlation for faces than for non-faces, indicating no disproportionate inversion effect for faces at the individual differences level. Our results cannot be accounted by task-related issues, because we obtained disproportionate face inversion effects at the group level, replicating the standard finding in the literature. Neither can they be accounted by reliability issues, because the reliabilities of the face and non-face tasks are comparable especially in Experiments 2 and 3. Finally, our study was not underpowered, because the sample size of our three experiments allowed us to detect moderate effects with at least 0.80 probability. Our findings indicate that although perception of upright and inverted faces differ in important ways, they may not always dissociate more than perception of upright and inverted non-faces do.

26.503 Perceived size, depth and distance of upright and inverted faces Yukyu Araragi[1](uqa@soc.shimane-u.ac.jp); [1]Shimane University

Araragi, Aotani, and Kitaoka (2012) reported the evidence for a size underestimation of upright faces compared to inverted faces, whereas the reason for it remains unclear. The present study examined the difference in perceptual depth and distance of face (or head) between upright and inverted faces using four photographic faces. An upright face and an inverted face were simultaneously presented, and were compared when they have same physical size, depth and distance. The results of Experiment 1 showed that there was no significant difference in perceptual depth between upright and inverted faces, whereas upright faces was perceived to be significantly smaller than inverted faces. The results of Experiment 2 showed that upright faces were perceived to be significantly further than inverted faces. These results suggested that the size underestimation was not due to perceptual depth and might affect the difference in perceptual distance between upright and inverted faces.

26.504 Mooney face pops-out in visual search Jessica Goold[1](jessi.goold@gmail.com), Ming Meng[1]; [1]Psychological and Brain Sciences, Dartmouth College

Faces seem to enjoy special advantages for human observers to process with remarkable speed and accuracy. For example, a face target may pop-out in a visual search task (cf. Hershler & Hochstein, 2005; VanRullen, 2006). However, it is debated whether special low-level image properties of the faces have led to this effect. To address this question, we tested human observers ability to process Mooney faces in a visual search task among non-face Mooney image distractors. Mooney images are two-toned images where a median luminance is found and all parts of the image with that luminance and higher were made white and all parts of the image with the lower luminance were made black. Many low-level visual features, such as luminance and contrast, were fully controlled for by using Mooney images. We present evidence that upright Mooney faces pop out in a visual search task, whereas inverted Mooney faces do not. Observers were able to detect target Mooney faces among non-face distractor Mooney images when the target face was upright faster than when the target face was inverted. Observers also acknowledged the absence of the target on catch trials more quickly when the target face was upright than inverted. Since one cannot rely on any local features to differentiate upright and inverted Mooney faces, our results indicate that instead of any low-level image properties, holistical representation of faces crucially underlies rapid and efficient visual processing of face images.
Acknowledgement: This work is supported by the National Science Foundation

26.505 The face inversion effect as an inefficiency in evidence accumulation Maxim Bushmakin[1](mbushmak@indiana.edu), Thomas James[1]; [1]Department of Psychological and Brain Sciences, Indiana University

Saturday PM

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. One example is the face inversion effect. Many researchers have found that there is an advantage for upright faces compared to upside down ones that is not observed with other types of objects (Rossion, 2008; Yin, 1969). A common explanation for these effects is that upright faces are processed by a holistic system while everything else – including inverted faces -- goes through a featural system (Maurer, Grand, & Mondloch, 2002; McKone, 2009). An alternative account is that there exists a single system and that variation in perception of different kinds of objects is due to differential tuning of the parameters of that system (Sekuler et al., 2004). Here, we examined these ideas with a formal Drift Diffusion model (Ratcliff, 1978; Ratcliff & Rouder, 1998). If upright and inverted faces are processed by different systems, then one would expect qualitatively different patterns of parameter values, with parameters for inverted faces matching objects (both upright and inverted) and parameters for upright faces being unique. However, based on the single-system account, we hypothesized that lower performance with inverted faces would reflect either a lower rate of evidence accumulation (drift rate) or a higher decisional threshold (criterion). The modeling results showed that the large inversion effects found with faces were mediated solely by the rate of perceptual evidence accumulation – none of the other parameters changed across orientation. This suggests that inverted faces are processed by the same system as upright faces and that the inefficiency associated with the face inversion effect is due to a slower accumulation of perceptual evidence.

26.506 Spatial memory for features in upright and inverted faces.

Lawrence Symons[1](Larry.Symons@wwu.edu), Cristina Sampaio[1]; [1]Psychology, Western Washington University

The present study assessed the memory for the position of a feature in upright and inverted faces. Computer generated faces were presented to observers who then had to replicate the position of an eye on a face with no eyes. Prior to the first experimental trial, we gathered data on the prototypical location of an eye in the face. Observers were presented with both an upright face and an inverted face (counterbalanced for order) with the eyes removed and were asked to position the mouse cursor where they thought one of the eyes belonged within the face. Observers exhibited more precise prototypical eye position for upright faces than for inverted faces. Specifically, the distribution of errors was narrower for upright than inverted faces. In the second task, faces were presented and observers then had to replicate the position of an eye on a face with no eyes. It was found that the spatial memory was biased towards the prototype to a greater degree in upright faces than the inverted faces. The results extend the literature on category effects on spatial memory and provide insight into the processing of upright and inverted faces.

26.507 Performance Consistency in Depth-Inversion Illusions: Faces and Scenes

Vanja Vlajnic[1](vvlajnic@eden.rutgers.edu), Thomas Papathomas[1,2], Steven Silverstein[3], Brian Keane[1,3]; [1]Center for Cognitive Science, Rutgers University, New Brunswick, [2]Department of Biomedical Engineering, Rutgers University, New Brunswick, [3]University Behavioral HealthCare, University of Medicine and Dentistry of New Jersey

Purpose: To assess the test-retest reliability in reporting depth-inverting illusions (DII) among healthy controls as a first step in testing differences with schizophrenia patients. Method: We assessed the illusion predominance (the percentage of time participants reported the illusory percept) for 12 subjects with bi-stable 3-D physical stimuli. Five stimuli were employed: two hollow faces (one realistically painted, PaintedHollowMask; the other unpainted, UnpaintedHollowMask); two reverse-perspective geometry scenes (one realistically painted, PaintedReverseScene; the other unpainted, UnpaintedReverseScene); and an unpainted convex face that should always be perceived as convex (CatchStimulus). Each stimulus was viewed twice for 2 minutes—once monocularly with subjects swaying left-to-right (to isolate motion parallax) and once binocularly with subjects on a chinrest (to isolate stereopsis). Subjects reported whether objects appeared convex or concave. Each subject repeated the same conditions in the same order, on average seven weeks later. Results: The illusion was strong for most stimuli. For first and second monocular/monocular and binocular/binocular viewings, illusion percent predominances were, respectively: PaintedHollowMask 90/62 and 59/42; UnpaintedHollowMask 65/63 and 34/38; PaintedReverseScene 92/90 and 74/54; UnpaintedReverseScene 75/70 and 38/37; CatchStimulus, as expected, 0/0 and 0/0. An intraclass correlation analysis was performed on the data to test for consistency. Overall, the IC coefficient (ICC) was acceptable. The average measures ICC's for the monocular/binocular conditions were: PaintedHollowMask 0.609/0.698, UnpaintedHollowMask 0.029/0.464; PaintedReverseScene 0.933/0.789, UnpaintedReverseScene 0.748/0.131; ICC not valid for CatchStimulus, because subjects always reported veridical percept. Discussion: The results indicate strong illusions, suggesting significant top-down influences in visual processing for scenes with strong linear perspective cues and for faces. The low ICC values for UnpaintedHollowMask and UnpaintedReverseScene suggest that we should prefer the painted mask and the painted reverse-perspective stimuli for the schizophrenia experiments. High ICCs suggest that the painted DII stimuli produce reliable performances across time.

26.508 Eye movements for scrambled faces

William G Hayward[1,2](whayward@hku.hk), Junpeng Lao[3], Zhijie Cheng[1], Kate Crookes[2,4], Tina T Liu[1], Roberto Caldara[3]; [1]Department of Psychology, University of Hong Kong, [2]ARC Centre of Excellence in Cognition and Its Disorders, [3]Department of Psychology, University of Fribourg, Switzerland, [4]Department of Psychology, University of Western Australia

We now have considerable evidence on the nature of face perception, and the way in which observers acquire information from intact faces in order to make judgments (e.g., identity, sex, age, ethnicity) about them. However, recent work has shown that faces can often be successfully recognized on the basis of individual features rather than the whole, intact face. Therefore, the goal of the current study was to investigate eye movements when participants were viewing sets of facial features that had been scrambled from their original configuration. Participants viewed scrambled and intact faces, in the context of a recognition memory test (where half the test items had been studied and half were new). During both study and test trials, fixation position was monitored. When presented with scrambled stimuli, fixations were largely centered on the two eyes, with relatively few fixations to the mouth, nose, or other features. With intact stimuli, however, fixations showed a different pattern, with more fixations to the nose and mouth (as well as to the eyes). We attribute this difference in eye movement patterns between intact and scrambled faces to the influence of the overall facial configuration in the former case. When facial features appear in the context of the intact facial configuration, the visual system is able to efficiently acquire information from across the whole face. Once the features are scrambled, however, observers appear to use a much more restricted focus of attention, which they position mainly on the eyes. These results also suggest that observers use a relatively small number of features as the basis for recognition decisions about scrambled faces.

Acknowledgement: This research was supported by a grant from the HK Research Grants Council (HKU744911)

26.509 Eye Movement Patterns Suggest Different Facial Features are Most Informative at Different Spatial Frequencies

Chantal L. Lemieux[1](clemi100@uottawa.ca), Elizabeth A. Nelson[1], Charles A. Collin[1]; [1]School of Psychology, University of Ottawa

While many studies have shown that a middle band of spatial frequencies (SF) is most useful for face recognition, others have pointed out that the most informative SF ranges vary depending on location on the face. In two experiments, we examined variations in the utility of different SFs across the face by measuring eye movements during an old/new recognition task using spatially filtered faces. Eye movements were recorded using the Eyelink II (SR-Research.com). In Experiment 1, we measured 32 subjects' eye movements during the learning phase of the old/new task; In Experiment 2 we examined 15 subjects' eye movements during the retrieval phase of the same task. Stimuli were 32 faces filtered to preserve 11 SF bands across the spectrum (bandwidth 2 octaves), plus an unfiltered baseline condition. Twelve areas of interest (AOIs) were defined for each face, and total fixation time was analyzed across AOI and SF. Results show that low SFs elicited more fixations on medial AOIs such as nose, forehead and chin. This may indicate a tendency towards holistic processing, whereby fixation on these features represents an attempt to take in the entire face. In contrast, high SFs elicited more fixations on inner features, such as eyes and mouth, suggesting greater featural processing. Analysis of gaze transitions across AOIs show that fixation patterns vary across SF. Specifically, subjects transition more between the inner features, and exhibit more transitions in general, when examining high SF faces. When looking at low SF faces, transitions tend to be few, and to stay within medial features such as nose, nasion and forehead. Our results are compatible with previous work suggesting that the useful SFs vary by face part. We also find evidence suggesting that low and high SFs respectively support holistic and featural processing.

Acknowledgement: NSERC

26.510 First fixations during face identification are invariant to rotation and scale

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Introduction: Previously we have shown that humans direct their initial eye movements during face identification to locations that optimize perceptual performance, both on the group and the individual level (Peterson & Eckstein, PNAS, 2012; Peterson & Eckstein, Psychological Science, in press). Here, we investigated whether this strategy, which is optimal for upright faces at common conversational distances, is maintained while identifying inverted and scaled faces. Methods: Observers completed three separate speeded (350 ms, time for one eye movement) tasks identifying faces embedded in white Gaussian noise (1 of 10 face identification). The first task asked observers to identify faces in an upright orientation and scaled to the size of a face at a normal conversational distance (6 degrees from the middle of the eyes to middle of the mouth). The second task had observers recognize the same faces while the images were rotated either 90° or 180° in plane. In the third task, observers identified the same faces at different scales, corresponding to looking at faces at different distances. Results: Observers displayed consistent initial eye movement patterns for upright faces, with an average landing position towards the vertical midline and displaced slightly downward from the eyes. This consistence was accompanied by inter-observer variability, with some observers fixating just below the eyes while a smaller subset looked further down towards the nose. Observers also displayed consistent and individualized first eye movements for horizontal, inverted, and scaled faces. Furthermore, these patterns were consistent for single observers across tasks: observers who looked close to the eyes on upright faces also looked close to the eyes on inverted and scaled faces. The results show that eye movement strategies that are optimized for common viewing conditions may be generalized to many less familiar situations.

Acknowledgement: NIH-EY-015925

26.511 **Where do we look when we look for emotion? The influence of cognitive and affective primes on fixations to the face and body**

Catherine Reed[1, 2](clreed@cmc.edu), Amanda Blattman[2], Rebekka Manzella[3], Leigh Milne-Wright[3], William Reed[1], Daniel McIntosh[4]; [1]Psychology, Claremont McKenna College, [2]Applied Cognitive Psychology, Claremont Graduate University, [3]Psychology, Pitzer College, [4]Psychology, University of Denver

Recent research has shown that both the body and the face are used to convey emotions, threat, and actions. Further, the communication of specific emotions relies differentially on face or body information. In this study we investigated whether gaze behavior to the face or to the body could predict the endorsement of anger, fear, threat, and direction judgments. We compared gaze behavior in no prime, cognitive prime, and affective priming conditions to determine how much of gaze behavior is influenced by the stimuli themselves relative to what information people are seeking and their internal bodily states. Finally, to differentiate the relative contributions of the face and body to judgments, we examined male and female congruent emotional stimuli (fear face/fear body; anger face/anger body) with incongruent emotional stimuli (fear face/anger body; anger face/fear body). For all conditions, the behavioral rating data confirmed that both the face and body are important sources of emotion, threat, and direction information: the incongruent stimuli were rated at intermediate levels relative to the congruent stimuli: faces were weighted more strongly for emotion and threat judgments and bodies were weighted more strongly for direction judgments. Analysis of gaze behavior showed differential fixations, time in regions of interest, and first fixations depending on condition, the congruency of the face/body emotion, and type of judgment. Thus, the perception of others' emotion and directional intent appears to be affected by both physiological and cognitive components, as well as the emotional congruency of the stimulus. Interestingly, first fixations were often on the body, which may suggest a prioritization of emotion information in the body, potentially to determine if a fast threat response was required. The examination of eye movements suggests that where one looks influences emotion perception and subsequent behavior.

26.512 **A prior for direct gaze**

Isabelle Mareschal[1,2](imareschal@gmail.com), Andrew Calder[3], Colin Clifford[1,2]; [1]School of Psychology, The University of Sydney, [2]Australian Centre of Excellence in Vision Science, [3]MRC Cognition and Brain Sciences Unit, Cambridge, UK

Introduction: Determining where someone else is looking is critical to successful social interactions. Surprisingly, however, very little is known about how others' direction of gaze is interpreted. Here we apply a Bayesian framework to determine whether normal adults have a prior expectation for the direction of someone else's gaze. Methods: Gaze discrimination thresholds were measured in normal adult participants using grayscale male and female synthetic faces whose eye deviations were independently controlled using Matlab procedures. Observers viewed the same face in a two-interval presentation and had to judge whether the gaze deviation in the second interval was to the left or to the right of the gaze in the first interval. Discrimination thresholds were measured around 5 baseline gaze deviations: direct, to the left and right of direct (e.g. ± 2deg) and extreme left and right deviations (e.g. ± 9deg). Observers performed the task in three different conditions: (a) no noise on the eyes; (b) noise on the eyes in both faces; and (c) a mixed condition with noise on the eyes in one face only. Results: Gaze discrimination thresholds were constant across the 5 baselines tested and raised when noise was added to the eyes. In the mixed condition, observers' biases were shifted in a direction consistent with the noisy stimulus being perceived as more direct. Likelihood functions were derived from the threshold data in conditions (a) and (b) and observers' data in the mixed conditions were fit with a Bayesian model. The model accounted for approximately 90% of the variance and estimates of the prior's peak were near direct. Conclusion: Our data suggest that the adult nervous system internally represents a prior for gaze as close to direct.

Acknowledgement: Australian Research Council and the Australian Centre of Excellence in Vision

26.513 **Detecting Gaze Direction in the Horizontal and Vertical Periphery**

Adam Palanica[1](apalanic@uwaterloo.ca), Roxane Itier[2]; [1]Department of Psychology, University of Waterloo, [2]Department of Psychology, University of Waterloo

Visual search paradigms have previously shown direct gaze (DG) to be detected better than averted gaze (AG). However, our previous eye-tracking research showed that this detection asymmetry is strongly influenced by the eccentricity at which the face is presented (Palanica & Itier, 2011). In four studies, we examined to what extent DG was better detected than AG in the periphery, using various horizontal and vertical eccentricities along the visual field. Stimuli consisted of frontal or deviated head views with direct- or averted gaze and were individually flashed across the screen as participants fixated the centre of the screen and discriminated gaze direction using a two-button press. Experiments 1 (frontal view) and 2 (deviated view) presented faces along the horizontal periphery; Experiments 3 (frontal view) and 4 (deviated view) presented faces along the vertical periphery. When the face was in frontal view, DG was detected faster and more accurately than AG across the entire horizontal visual field, as well as across the vertical visual field tested. When the face was in deviated view and presented along the horizontal periphery, AG was detected faster and more accurately than DG in the periphery, while DG was detected faster in the central visual field. When the face was in deviated view and presented along the vertical periphery, DG tended to be detected faster than AG at some eccentricities, but no RT difference was found. Overall, these findings suggest that gaze direction can be discriminated in both the horizontal and vertical periphery. Importantly, the congruency between gaze direction and head orientation seems to be play an important role. These findings demonstrate that the speed and accuracy of gaze detection is highly dependent on target position and head orientation.

26.514 **Revisiting the Wollaston Illusion: Categorical perception of gaze**

Timothy Sweeny[1](timsweeny@gmail.com), Tessa Kayser[1], Erika Gonzalez[1], David Whitney[1]; [1]Department of Psychology, University of California, Berkeley

A person's gaze reveals much about their focus of attention and desires, and as such, perceiving gaze is important for typical social interaction. The direction of a person's gaze is determined by integrating local information from the eyes with the rotation of the head. This interaction produces a striking illusion, known as the Wollaston effect, where a person's gaze is pulled in the direction of the head's rotation. If perceiving gazes directed toward one's self is especially important, then the visual system may optimize this integration around the categorical boundary of leftward/rightward gaze and produce a repulsive perceptual effect. We tested this prediction and found converging evidence to support it. First, head rotations around the leftward/rightward category boundary produced a stronger pull on perceived gaze than equivalent rotations further away from the boundary (e.g., slightly rotating a straightforward head pulled gaze by 8º, whereas an equivalent rotation of an already-rotated head only pulled gaze by 4º). Second, the magnitude of this pulling effect was strongest when local eye information was near the category boundary; head rotations pulled straightforward eyes more strongly than they pulled averted eyes. The illusion we utilized is predicated on the integration of local information across a head, suggesting that the categorical perception of gaze originates in high-level stages of visual processing. Our results combine with similar findings in the perception of biological motion to provide growing evidence that repulsive effects underlie the categorical perception of many social features.

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26.515 Contribution of cardinal orientations to the "Stare-in-the-crowd" effect

Valerie Goffaux[1, 2](valerie.goffaux@ppw.kuleuven.be), Sanae Okamoto-Barth[2]; [1]Laboratory of Biological Psychology, KU Leuven, Belgium, [2]Department of Cognitive Neuroscience, Maastricht University, The Netherlands

Evidence shows that the processing of face identity relies on horizontally-oriented cues, with little contribution of vertically-oriented cues. Besides identity, faces convey a wealth of fundamental social cues such as gaze. We investigated whether the processing of gaze is tuned to horizontal orientation as observed for identity. Participants were presented with arrays of six faces and instructed to search for a target face with either direct gaze (DG) or averted gaze (AG). The "stare-in-the-crowd" effect refers to the observation that DG is more easily detected than AG. Faces were filtered to preserve a 20°-orientation content centered either on horizontal or vertical orientation (H and V condition, respectively). In a third condition, horizontal plus vertical information was preserved (HV) by summing the H and V filtered images. Our results replicate the "stare-in-the-crowd" effect; namely, detecting DG was overall more accurate and faster than detecting AG. More importantly, the "stare-in-the-crowd" effect was significant only for vertically-filtered faces, in trials where a DG target was present. The same pattern was observed on RT. These findings suggest that although horizontal information is central for the processing of face identity, vertical information contributes to the processing of some core social signals conveyed by faces.

Face perception: Identification

Saturday, May 11, 2:45 - 6:45 pm

Poster Session, Vista Ballroom

26.516 Representations of face identity information in ventral visual stream using multi-voxel pattern analyses

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The neural basis of face recognition has been extensively investigated. Using functional magnetic resonance imaging, several regions have been identified in the human ventral visual stream that seem to be involved in processing and identifying faces, but the nature of face representations in these regions is not well known. In particular, multi-voxel pattern analyses (MVPA) have revealed distributed maps within these regions, but did not reveal the organizing principles of these maps. We isolated different types of perceptual and conceptual face properties to determine which properties are mapped in which regions. A set of faces was created with systematic manipulations of featural and configural visual characteristics. The face set consisted of 9 faces (one base face and 8 faces equally different from the base face), differing from each other in terms of featural information (with differences in eye colour, eyebrow thickness and lip thickness), and configural information (eyes apart or close together, mouth up or down). In a second part of the study, context information was added to most of the faces (a name, location and occupation). Data were analyzed by training linear support vector machines (SVMs) to classify multi-voxel pattern analyses. Maps in face-selective regions represented both configural and featural differences between faces. Fusiform and more anterior temporal face-selective patches also represented whether or not a face had been trained (associated with a background story), but could not distinguish between the two locations with which the faces were associated. In contrast, the non-face-selective parahippocampal place area represented which context information was associated with a face (differentiating between faces associated with the same or a different location). Together, these findings demonstrate how regions that are often treated as unitary modules contain distributed maps that have specific properties and that show a progression from purely visual maps to context-driven maps.

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26.517 Neural adaptation is sensitive to the gamut and division of a stimulus space

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Recent research (Kahn, Mattar, & Aguirre, SfN 2012) has suggested that the gamut of a stimulus set affects the form of neural encoding, as measured by neural adaptation or norm-based effects. In addition, it has been long argued that the number of exemplars (divisions) along a single dimension plays a role in perception, regardless of gamut (Miller, 1956; Shiffrin & Nosofsky, 1994). We sought to investigate the influence of both gamut and division on neural encoding effects related to face similarity. 8 pilot subjects viewed subsets of a linear face morph space presented using a carry-over design (Aguirre, 2007) while event-related potentials were measured. In three different experiments (with counter-balanced order across subjects) the stimuli used either densely sampled the whole space (9-stimuli, full gamut), densely sampled part of the space (5-stimuli, narrow gamut), or sparsely sampled the whole space (5-stimuli, full gamut). Our preliminary findings replicate prior work (Kahn, Harris, Wolk, & Aguirre, 2010), demonstrating a linear recovery from adaptation within the P200 component of the evoked response proportional to the metric similarity of a 5-step, full-gamut morph of two face identities. We expected that as the number of morphed steps increased between the two face identities, that the degree of adaptation resulting from small stimulus transitions should demonstrate a floor effect. Our measure of adaptation within the P200 appears to exhibit this floor effect when the number of face morph exemplars reaches 9 across the full morph gamut. Interestingly, the pattern of adaptive effects resulting from the 5 stimulus narrow-gamut space does not readily correspond to the pattern of either of the other two, suggesting a more complex model of early perceptual encoding may be necessary.

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26.518 The neural correlates of covert recognition of familiar faces

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It is well established that our brains are highly sensitive to face. We can easily recognize a face even it is seriously degraded. Specially, our brains can even make a response to a face of which we can not overtly be aware. A good many of studies have reported such covert or unconscious face recognition. However, little is known about the neural correlates underlying such face processing. Patients with acquired prosopagnosia may be a good mode for the investigation of the neural mechanism of covert face processing, because they are unable to consciously identify the faces with which they were very familiar previously after the onset of their diseases. Here, we use fMRI methodology to compare the brain activities between a prosopagnosic patient and normal controls when they viewed famous face and unfamiliar face stimuli. We found that the FFA of the patient was activated only by famous faces relative to common objects stimuli. In contrast, the FFA of the normal controls was activated by both famous faces and unfamiliar faces. Further, when comparing the fMRI activities of famous face to those of unfamiliar faces, the normal controls showed enhanced activation in the lateral prefrontal cortex and right posterior parietal lobule (Figure 1). Such brain regions have been suggested to be involved in the overt processing of face identity information. In contrast, using the same contrast as the normal controls, the patient did not show enhanced activities in such regions, but instead presented greater activation in the medial prefrontal cortices (Figure 2). Our findings suggested that the FFA may be involved in both overt and covert face processing, and the patient' s impairment in overt recognition of famous faces is likely to be due to the absent activation of the lateral prefrontal cortices and right posterior parietal lobule.

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26.519 Normal sensitivity to facial identity in right anterior inferotemporal face-selective region in the absence of right fusiform face area

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Multiple face-selective cortical regions have been identified in humans, but the function of each region and the relationship between them remains unclear. We addressed this issue by examining the effect of a lesion to a posterior region in the face network on the functioning of a more anterior region. Galen is a 30-year-old right-handed male who became prosopagnosic after a surgery to remove a cerebral arteriovenous malformation (AVM) in his right occipito-temporal cortex. A structural scan revealed lesions on the right side extending from the temporal lobe to the occipital lobe, as well as a small part of right cerebellum. A localizer scan showed that Galen's right fusiform face area (FFA) was missing due to the lesion. Other face-selective areas were present including bilateral occipital face area (OFA), bilateral posterior superior temporal sulcus (pSTS), bilateral anterior STS (aSTS), and left FFA. Most importantly for the current study, bilateral regions in Galen's anterior inferotemporal cortex (aIT) also showed a face-selective response. We used fMRI-adaptation to investigate the sensitivity of Galen's aIT to facial identity. On each trial, two different images of the same celebrity or two different celebrities (age- and sex-matched) were presented. In the scanner, Galen and nine control participants judged whether pairs of images showed the same celebrity, and as expected, Galen's discrimination ability was significantly worse than the controls. The control group showed significant repetition suppression for the same identity pairs in right aIT. Surprisingly, Galen's right aIT showed repetition suppression comparable to that seen in the controls. This finding demonstrates that the right aIT can preserve its face-selectivity and continue to represent identity information despite of the loss of the right FFA.

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26.520 **The Relative Role of Eyes, Eyebrows, and Eye Region in Face Recognition** Charles Saavedra[1](Charlestar30@gmail.com), Pamela Smith[2], Jessie Peissig[3]; [1]Department of Psychology, California State University, Fullerton, [2]Department of Psychology, California State University, Fullerton, [3]Department of Psychology, California State University, Fullerton

Previous studies have shown that the eye region is critical for face recognition. However, there has been little done to explore the individual contribution of the eyes and eyebrows alone. The purpose of the current study is to expand on past research and consider the individual contributions of the eyes and eyebrows in face recognition. Twenty-nine individuals were asked to decide whether two faces shown in succession were the same person or different people. In the trials where the faces were the same, participants were presented with the original face twice or the original face and the same face with one of six digital manipulations. The manipulations consisted of either erasing or replacing the eye area, the eye, or the eyebrows in each face. Participants were also presented with an equal number of trials in which the faces were not the same. Overall, results showed that there was a significant main effect of condition on same trials. In comparison to the no manipulation condition, there was a significantly lower proportion correct value for the erased eyebrow condition; however, the changed eyebrow condition did not reach significance. Interestingly, the opposite relationship was found for conditions where the eye and eye area was either changed or erased. Results showed that participants exhibited a significantly lower proportion correct for the changed eye and eye region conditions; in contrast, the difference in the erased eye condition was not significantly different from original/original trials. These results suggest that both the eyes and eyebrows on their own are important for face recognition, but that their roles are different. While the eyebrows may be largely used as a place marker for estimating distances among the parts of the face, the eyes themselves are used primarily as a distinguishing face part.

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26.521 **Masking of individual facial features reveals the use of horizontal structure in the eyes** Matthew V. Pachai[1](pachaim@mcmaster.ca), Allison B. Sekuler[1,2], Patrick J. Bennett[1,2]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University, [2]Centre for Vision Research, York University

We previously demonstrated that information in the horizontal band is maximally diagnostic for face identification, and the extent to which observers preferentially utilize this information is correlated with their face identification accuracy (Pachai et al., VSS 2011). However, it remains unclear how this diagnostic information is distributed across the face, and from which regions observers extract this information. The present experiment addressed these questions using a 10-AFC face identification task in which stimuli were masked with localized patches of white, horizontal, or vertical noise at one of four rms-contrast levels (0.01, 0.1, 0.2, and 0.3) centred on one or more face parts (left eye, right eye, nose, and mouth). The various noise types and contrasts, plus a no-mask condition, were intermixed randomly within sessions, and the various mask locations were blocked across sessions. A template-matching simulated observer demonstrated more masking with noise centred on either eye than the nose or mouth, and more masking with horizontal than vertical noise centred on either eye or the mouth, supporting the idea that the eyes are maximally informative for face identification, and that the eyes and mouth contain diagnostic horizontal structure. In human observers, masking was negligible when noise was centred on any single feature regardless of noise contrast. Observers also demonstrated a minimal threshold increase when we simultaneously masked the nose/mouth or one eye/nose/mouth. However, thresholds were elevated significantly at multiple noise contrasts when both eyes were masked simultaneously, and greater masking was obtained with horizontal than vertical noise. Efficiency relative to the template-matching observer also was higher when at least one eye was unmasked than when both eyes were masked. Together, these results suggest that human observers preferentially utilize diagnostic horizontal structure contained in the eye/eyebrow region to identify upright faces, and that performance suffers when this information is rendered unavailable.

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26.522 **Temporal frequency tuning of individual faces is independent of the proportion of different face identities in a sequence of stimulation** Francesco Gentile[1](f.gentile@maastrichtuniversity.nl), Joan Liu-Shuang[1], Bruno Rossion[1]; [1]Face categorization lab, University of Louvain, Belgium

In everyday life, we are constantly presented with a large amount of different faces that we need to discriminate. Recently, we used a face adaptation paradigm to investigate the extent to which this process is modulated by the temporal rate at which faces are presented, both with electroencephalography (EEG) and functional magnetic resonance imaging (fMRI) (Alonso Prieto E and B Rossion, 2011; Gentile F and B Rossion, 2012, respectively). In these studies, participants were presented with sequences of different and identical faces at several temporal frequencies ranging from 1 Hz (1face/second) to 12 Hz (sinusoidal contrast modulation, as in Rossion B and A Boremanse, 2011). In both studies, neural adaptation (signal difference between different and identical faces) peaked at 6Hz and decreased for higher frequency rates. Even though we ensured that an individual face was never repeated consecutively, the amount of different faces presented in the different condition for all temporal frequencies was fixed. Therefore, the number of face repetitions was larger at higher frequency rates of presentation. In order to control for such a potential confound we ran an EEG (N = 8) and fMRI (N =4) experiment with variable amounts of different faces in each block of stimulation (10, 20, 50, 100 in EEG; 18, 36 in fMRI), at two different frequencies (6 and 12 Hz). For both frequencies tested, neither the fMRI nor the EEG signal was modulated by the number of different faces presented in a block. This result indicates that the decrease of neural adaptation between 6 and 12 Hz cannot be explained by an increase of individual face repetitions at high frequency rates.

26.523 **How Dynamic Facial Cues, Stimulus Orientation and Processing Biases Influence Identity and Expression Interference** Sarah Rigby[1](sarahrigby@mymts.net), Brenda Stoesz[1], Lorna Jakobson[1]; [1]Department of Psychology, Unviversity of Manitoba

Research using Garner's selective attention paradigm suggests that, when we view static faces, the processing of facial identity interferes with the processing of expression, and vice versa (Ganel & Goshen-Gottstein, 2004). We recently replicated this result, but went on to show that interference is negligible when dynamic faces are viewed (Stoesz & Jakobson, submitted). This "dynamic advantage" could arise if, with the introduction of dynamic cues, viewers shift from using a global processing approach to focusing on local facial features (see Xiao et al., 2012). If this is the case, the advantage should be most apparent with upright stimuli, and in those with a global processing bias. To test these ideas, we assessed participants' processing style using hierarchical stimuli, and then had them make speeded expression (or identity) judgements of static and dynamic faces presented in upright and inverted orientations while identity (or expression) was held constant (baseline block) or varied (orthogonal block). We calculated (a) corrected interference scores by determining the percent change from baseline RT seen in the orthogonal block; and (b) dynamic advantage scores by finding the difference between static and dynamic interference scores for each condition. As in our earlier work, interference was seen with static but not with dynamic stimuli, and the dynamic advantage was more evident with the expression than the identity task. However, planned comparisons revealed that the dynamic advantage seen during expression processing was eliminated after stimulus inversion for individuals showing a global (but not a local) processing bias. These results are consistent with the view that, when making expression judgments, global processors respond to the introduction of dynamic cues by switching to the use of a local processing strategy. Our findings highlight the importance of using dynamic displays and of considering individual differences when characterizing typical face processing mechanisms.

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26.524 **The time course of chromatic and achromatic information extraction in a face-gender discrimination task** Kim Dufresne[1](kim.dufresne@umontreal.ca), Laurent Caplette[1], Valérie English[1], Maxime Fortin[1], Mélissa Talbot[1], Daniel Fiset[2], Frederic Gosselin[1], Nicolas Dupuis-Roy[1]; [1]Psychology, University of Montreal, [2]Psychoéducation et de Psychologie, Université du Québec en Outaouais

A previous study using the Bubbles technique (Dupuis-Roy, et al., 2009) showed that the eyes, the eyebrows, and the mouth were the most potent features for face-gender discrimination (see also Brown & Perrett, 1993; Russell, 2003, 2005). Intriguingly, the results also revealed a large positive correlation between the mouth region and rapid correct answers. Given the highly discriminative color information in this region, we hypothesized that the extraction of color and luminance cues may have different time courses. Here, we tested this possibility by sampling the chromatic and achromatic face cues independently with spatial and temporal Bubbles (see Gosselin & Schyns, 2001; Blais et al., 2009). Ninety participants (45 men) completed 900 trials of a face-gender discrimination task with briefly presented sampled faces (200 ms). To create a stimulus, we first isolated the S and V channels of the HSV color space for 300 color pictures of frontal-view faces (average interpupil distance of 1.03 deg of visual angle) and adjusted the S channel so that every color was isoluminant (±5 cd/m2); then, we sampled S and V channels independently through space and time with 3D Gaussian windows. The group classification image computed on the response accuracy revealed that in the first 60 ms, participants used the color in the right eye-eyebrow and mouth regions, and that they mostly relied on the luminance information located in the eyes-eyebrows regions later on (>60 ms). Further classification images were computed for each gender-stimulus category. The results indicate that chromatic information in the mouth region led to systematic categorization errors. An analysis of the chromatic information available in this facial area suggests that this is not due to our face database, but rather represents a perceptual bias. Altogether, these results help to disentangle the relative contributions of chromatic and luminance information in face-gender discrimination.

26.525 **Describing the temporal dynamics of the face familiarity effect: Bootstrap analysis of single subject ERP data**

Esther Alonso-Prieto[1](esther_alonso_prieto@yahoo.com), Raika Pancaroglu[1], Kirsten A. Dalrymple[1], Jason JS Barton[1], Ipek Oruc[1]; [1]University of British Columbia

Background: Evoked potential studies of familiarity effects on face processing have lead to divergent conclusions, with some suggesting that they emerge as early as 140-170ms, and others later, around 250-400ms. However, those reports rely on group averages of mean or peak amplitude within a priori time windows. Objective: Our goal was to determine the temporal dynamics of the familiarity effect at the level of the individual subject, using a moving window analysis that did not make assumptions regarding specific time windows. Methods: 10 observers judged the pleasantness of faces presented in a screen. A trial started with a fixation point (2700-2900ms) followed by an anonymous or a familiar (internet celebrity pictures) face (100ms) and a mask (300ms). Results contrasting anonymous versus familiar faces were analyzed using a point-by-point bootstrap analysis of single subjects (Figure 1). Results: Significant differences between familiar and unfamiliar faces were most consistently found between: 80-120ms in O1, O2, Oz; 120-140ms in Fz, Cz, Pz; 140-160ms in P8, 160-180ms in P7; 300-360ms in Fz, Cz, Pz (Figure 2). As the earliest differences were observed in occipital electrodes, these may reflect differences in stimulus properties between the anonymous and famous images. However, differences at 120-180ms appeared at times and in locations where face-selective responses occur (the N170 in P8/7 and VPP in Pz/Cz) and not in occipital electrodes, suggesting that they reflected modulation of face-processing by familiarity. Less consistent differences observed after 300ms in central electrodes coincide with the P300 component, which has been associated to processing novel stimuli. Conclusion: This approach suggests that familiarity effects on face processing emerge around 120ms and evolve dynamically across the scalp, probably reflecting the activation of a widespread face perception network. Central derivations manifest such influence first, followed by temporo-occipital locations in the right and finally in the left hemisphere.

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26.526 **The Short-term Temporal Dynamics of the Face Identity After-effect: an Adaptation-Interference Study**

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Background: The duration of aftereffects depends on the adaptation duration, the time lag between adapting and test stimuli, and the duration of the test stimuli. However, while there is data suggesting that face aftereffects may last days, not much is known about the short-term temporal decay of aftereffects and the influence of intervening stimuli. Objective: Our goal was to investigate the magnitude of face identity aftereffects across variable delay periods and to determine the effects of other faces during these intervals. Methods: In Experiment 1, subjects performed a face adaptation task, in which an adaptor period was followed by a 150ms 'interference' interval, and then the ambiguous probe image. There were three conditions: 1) faces in the adaptor period, blank in the interference interval, 2) adapting face in the adaptor period, opposing face in the interference interval, and 3) a face in the interference interval, no stimulus in the adapting period. In Experiment 2, subjects performed a similar task, but with interference intervals of 300ms, 1500ms, and 3000ms, and unrelated faces as interfering stimuli. Results: Experiment 1 showed that a brief 150ms presentation of a face caused a slight attractive aftereffect of about 13%, while the adaptor stimulus alone caused a repulsive aftereffect of 27%. Having the interference face follow the adaptor did not decrease the aftereffect, though variance was substantially increased. Experiment 2 showed that the aftereffect of adaptors alone showed a trend to decrease by about half over 3000ms, from 23% to 12%. A face in the interference interval caused aftereffects to decline by about half, to 11%, for the 300ms interval, but had no effect in longer intervals. Conclusion: These results show there is a modest but rapid short-term decline in the magnitude of the face identity aftereffect, and that a following face may accelerate this decline.

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26.527 **The dynamics of adaptation to fast periodic visual stimulation**

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A recent study showed that electrical (EEG) response to fast periodic visual stimulation (FPVS, i.e., 4 Hz) recovers immediately when a different face identity is presented in a periodic train of identical faces (Rossion et al., 2012, NeuroImage). The effect, localized over the right occipito-temporal cortex (OTC) and specific to the stimulation frequency, is much reduced when faces are inverted or contrast-reversed. These findings showed that FPVS represents a powerful tool for estimating visual cortex sensitivity to high-level visual manipulations. The present study was designed to clarify further the temporal dynamics of the fast periodic adaption itself. It was based on the hypothesis that initially, periodic presentation of exactly identical faces tends to induce stronger and faster response entrainment than different face identities (Rossion and Boremanse, 2011), counteracting visual adaptation effects. Here the onset of periodic response and adaptation were separated by reversing the order of stimuli sequences: we induced the fast periodic response by presentation of different faces for 15 seconds, and then introduced identical faces to study the dynamics of adaptation after the system has been periodically entrained. Thirteen subjects were presented with 74-s trials (with 15-s long initial different faces sequences) in which faces appeared at a constant rate of 5.88 Hz and high-density (128 channels) EEG signal was recorded. Compared to a sequence in which only different faces were presented, we found large adaptation effects (i.e., reduction of EEG amplitude at the periodic rate of stimulation) to the repetition of the same face identity, mainly over the right occipito-temporal cortex. However, contrary to the fast release from adaptation observed previously (Rossion et al., 2012), the amplitude reduction took several seconds following the introduction of a repeated face, suggesting that generalization to the same face identity has a slower temporal dynamics than detection of changes of identities.

26.528 **Adaptation Aftereffects for Face-Halves and the Eye-Region**

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Background: There is considerable evidence that faces are processed as 'wholes' in the human visual system; however, there is also evidence of a feature-salience hierarchy, in that some features contribute more than others to facial percepts. Whether this is true of the neural representations of faces is not known, but a question that can be explored through the use of face adaptation. Objective: We used a perceptual bias technique to determine if there are differential contributions to identity aftereffects from the lower face, upper face, and eye region. Method: We selected two unfamiliar face pairs from the HVEM face database with equivalent physical similarity, as determined by a Bayesian ideal observer technique, and created full-face morphs between each of these face pairs with 2.5% increments, which would serve as probe stimuli. For adapting images, we used (1) the whole unmorphed faces, (2) divided these unmorphed faces into upper and lower halves, and (3) isolated a horizontal band containing the eyes alone. In the first experiment we compared the magnitude of aftereffects generated by whole faces, upper faces and lower faces. In the second experiment we compared the aftereffects from whole faces, upper faces and the eye-band. Results: Upper faces generated aftereffects that were not statistically different from whole faces, while lower faces did not generate significant aftereffects. The eye region generated aftereffects that were not statistically different from those generated by the upper face. Conclusions: The upper face and in particular the eye region form a dominant component of the aftereffects for facial identity, suggesting an important role for these regions in the neural representation of facial identity. This is consistent with evidence from discrimination experiments for a feature-salience hierarchy in human face perception.

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26.529 Fine-grained individual face discrimination as evidenced by fast periodic visual stimulation Adelaide de Heering[1](adelaide.deheering@uclouvain.be), Joan Liu-Shuang[1], Anthony Norcia[2], Bruno Rossion[1]; [1]Department of Psychology, University of Louvain, Belgium, [2]Department of Psychology, Stanford University

Fast periodic visual stimulation can be used to rapidly and objectively measure individual face discrimination (Rossion & Boremanse, 2011), with an optimal frequency rate of about 6 Hz (Alonso-Prieto & Rossion, 2012). Here we defined the tuning function for fine-grained individual face discrimination with a rapid oddball paradigm (Liu-Shuang et al., 2012). High density EEG (128-channels) was recorded in 10 participants presented with 40-second sequences of faces appearing at a rate of 5.88 Hz (sinusoidal contrast modulation, Figure 1). Each stimulation sequence contained a series of 4 repetitions of an identical original face (A, 0% morph) followed by a morphed face (B) (i.e., AAAABAAAABA…). The morphed face (B) differed from the original face (A) from 0% (same identity) to 100% (different identity), in 10% steps, for a total of 44 sequences presented in random order. EEG signal-to-noise ratio (SNR) at the identity-change frequency (every 5 stimuli, or 5.88 Hz/5 = 1.18 Hz) and its harmonics (2F/5 = 2.35 Hz, 3F/5 = 3.53 Hz, 4F/5 = 4.70 Hz) was used as a neural index of individual face discrimination (Liu-Shuang et al., 2012). Significant SNR increases were found over the right occipito-temporal cortex at the identity-change frequency and its harmonics for stimuli that differed by more than 40% of identity information, with no such evidence before this threshold (Figure 2). A complementary behavioural experiment supported the presence of a shift in the tuning function for fine-grained individual face discrimination even though participants' results were more variable than in the EEG experiment. Overall, these findings indicate that the coding of individual faces in the occipito-temporal cortex is non-linear with respect to physical similarity between faces. They also highlight the power of the fast periodic visual stimulation approach in EEG to characterize individual face perception at a fine level.

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26.530 Contrasting the use of interattribute distances with that of all other face-gender discrimination cues Nicolas Dupuis-Roy[1](nicolas@dupuis.ca), Laurent Caplette[1], Couet-Garand Alexandre[1], Valérie English[1], Maxime Fortin[1], Mélissa Talbot[1], Daniel Fiset[2], Frederic Gosselin[1]; [1]Psychology, University of Montreal, [2]Psychoéducation et de Psychologie, Université du Québec en Outaouais

The use of relational cues such as the distances between the main internal features of a face (interattribute distances; IADs) is believed to be a distinctive and critical aspect of face processing (Maurer et al., 2002). Yet, little is known about the information contained in real-world relational cues compared to other facial cues, and the relative ability of humans to use these cues. Recently, Dupuis-Roy et al. (2012) found that observers performed rather poorly in a face-gender discrimination task when only real-world IADs were available. However, given the scarce information in these cues, this low performance amounted to a high efficiency. To date, no study has ever systematically compared the efficiency associated with real-world IADs to the efficiency associated with the remaining gender-discriminative cues. This was the aim of this follow-up study. Thirty observers (15 females) completed three face-gender discrimination tasks: Task 1 tested the performance when solely real-world IADs were available; Task 2 measured the performance when all cues except IADs were available; and Task 3 assessed the performance when all cues were available. Each task had 1000 trials (500 female faces). To assess the information available in each task, three regularized linear classifiers were first trained on 250 face stimuli and tested on 250 novel ones. The observers' sensitivity measure was then combined with the respective ideal observer's sensitivity to compute an efficiency index. Results revealed higher efficiencies in task 1 (IADs only) than in task 2 (all cues except IADs) and task 3 (all cues), suggesting that participants are better at using the available scarce IADs information than any other facial cues. A further analysis comparing the observed performance in task 3 and the one predicted by a linear combination of the other two tasks, suggests a suboptimal integration of the available information.

26.531 Photographic Clarity and Blur Influences Person Perception James T Enns [1](jenns@psych.ubc.ca), Sarah C MacDonald[1]; [1]Department of Psychology, University of British Columbia

The selective blurring and sharpening of images is used by filmmakers, photographers, and artists (1) to guide visual attention and (2) to influence the emotional experience of the viewer. This study tests this two-part hypothesis by first using an eye tracker to measure the influence of selective blurring and sharpening on looking behavior. Thirty participants viewed twenty-four photos of couples for seven seconds each, before being asked to answer four Likert-scale questions about the personality of one of the people in the photo. The results showed that although viewers were instructed to look equally at both people, they generally looked first, and more often, at faces rendered in sharper focus relative to other faces. In the second phase, we measured the consequences of this selective looking on the attributions viewers make to the people depicted in photos. The results indicated that both longer looking times and image clarity played a role, although their relative importance depended on the dimension being queried. For example, while attractiveness ratings were positively correlated with overall viewing time there was an additional effect linked to image features (i.e., slightly blurred persons were judged as more attractive than an equivalent slight sharpening). For dimensions tied more closely to personality, viewing time seemed to play no role, but image features did (e.g., sharper faces received higher sociability ratings but lower trustworthiness ratings). These findings imply that person perception is influenced by superficial image features in much the same way that it is influenced by a person's physiognomy (Willis & Todorov, 2006). Our interpretation is that person perception is susceptible to inverse inferences deriving both from our own actions (e.g., looking longer leads to increased interest and value) and from a false understanding of the source of the image features (e.g., more self-revealing people are sharper in photos).

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26.532 Effect of size on the perception of identity in blurry faces Kimia Shahangian[1](kshahangyan@hotmail.com), Ipek Oruc[1]; [1]UBC Ophthalmology and Visual Sciences

It is commonly accepted that face perception relies on middle spatial frequencies around 8 cycles per face-width. However, it has recently been shown that the spatial frequencies critical for face recognition is not fixed but rather depends on size (Oruc and Barton 2010). This effect is especially pronounced at small sizes, where recognition is mainly based on low spatial frequencies (i.e. gross forms in the image), compared to larger sizes where middle frequencies, which include finer details, are used. This scale-dependent recognition strategy has been shown in the context of just-visible face images. However, whether this would hold for supra-threshold perception is not clear. We address this question using an adaptation paradigm. We examine face identity aftereffects using blurry and intact adaptors of two different sizes: small (2 deg) and large (10 deg). The blurry adapting faces included the low spatial frequencies hypothesized to be used at the small size, but not the higher portion of the spectrum used at the larger size. Intact adaptors induced significant aftereffects regardless of size. The blurry adaptor similarly produced aftereffects that were as large as the intact adaptors, but only at the small size. In contrast, the large blurry adaptor failed to generate any aftereffects. Since the large blurry adaptor was physically identical to the small one and therefore contained the same identity information, the lack of obtaining any identity aftereffects suggests that the observers were not able to access this low-frequency information for the purposes of perceiving identity specifically at this large size. Overall, these results confirm that size is a determining factor in processes of face perception. Importantly, our results suggest that degraded blurry faces are easier to recognize at smaller sizes (i.e. at farther viewing distances).

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26.533 Individual face representation limits the precision of average face representation Jason Haberman[1](haberman@wjh.harvard.edu), Julie Belkova[2], George Alvarez[1]; [1]Department of Psychology, Harvard University, [2]Department of Psychology, Simmons College, [3]Department of Psychology, Harvard University

A wealth of evidence suggests that the visual system can compress redundant information into ensemble representations. These representations are derived efficiently and across multiple visual domains (e.g., average orientation, average faces). An unresolved question is whether ensemble representations are computed in a separate visual processing stream from individual object representations. We examine this question using an individual differences approach, assessing the relationship between single item representations and average representations. Observers viewed sets of four faces varying subtly in identity. On individual trials, a box surrounded one of the faces, indicating the single target they should encode. On ensemble

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trials, a box surrounded the whole set, and observers had to encode the average of all the faces. Using continuous report, observers then adjusted a test face to match what they had just encoded: either a single face from the set or the average face of the set. Individual item precision and ensemble representation precision were assessed using average error (i.e., how far an observer's response was from the actual correct answer, on average) – the smaller the error the more precise the representation. Because we were interested in individual differences, each participant received identical trials (i.e., same displays in the same order), so that differences across individuals cannot be explained by display differences. Our measures were highly reliable, as indicated by Cronbach's alpha (individual r=.76; ensemble r=.64). Moreover, the correlation between individual and average face representations was strong (r=.72), approaching the maximum possible given the reliability of our measures. These results suggest that average face representations are computed over individual face representations and are therefore limited in large part by factors influencing individual face perception. While future work must account for general factors that drive these correlations, the current work lays a framework for understanding the mechanisms supporting ensemble processing.

Acknowledgement: NIH, NSF

26.534 **Ensemble Crowd Perception: A Viewpoint Invariant Mechanism to Represent Average Crowd Identity** Allison Yamanashi Leib[1](ayleib@gmail.com), Jason Fischer[2], Yang Liu[1], David Whitney[1], Lynn Robertson [1]; [1]University of California Berkeley , [2]Massachusetts Institute of Technology

We encounter crowds of faces all the time in our daily lives. Previous work has demonstrated that we are surprisingly sensitive to high-level summary statistical information, such as average expression (Haberman & Whitney, 2007), and this high-level summary encoding has been shown in both space and time (Haberman & Whitney, 2009; Albrecht & Scholl, 2010). In the real world, faces are often randomly oriented. However, previous work on ensemble or summary statistical perception has not clarified whether these percepts can be formed from viewpoint invariant object representations. If summary statistical perception operates over the viewpoint invariant 3D representations of objects, this would broaden the applicability and usefulness of ensemble coding throughout natural scenes, including faces in a crowd. Here, we presented a temporal sequence of faces. The number of faces in each sequence (crowd) varied ranging from 2-18 faces. Each individual face was viewed for 47 ms. The sequences contained leftward-orientated faces, and participants were asked to report the mean identity using an adjustable, forward-oriented test face. Our results indicate that participants achieve a veridical ensemble code even when required to view the faces in one orientation and respond in a new orientation. We varied set sizes as a control to measure how much information was integrated from each set of faces. Using this control, we found that participants were integrating on average 4 or more faces in the stimuli set. Thus, alternative explanations, such as 1 face subsampling, cannot adequately explain the participants' results. This pattern of performance suggests that an ensemble percept is not strictly image-based, but depends on object-centered representations that can be successfully utilized under conditions of viewpoint invariance

26.535 **Face contour is crucial to the fat face illusion** Yu-Hao Sun[1,2](yuhao.sun@gmail.com), Zhe Wang[2], Paul Quinn[3], Naiqi Xiao[1], Huimin Shi[2], Ming Zhong[2], Haiyang Jing[2], Liezhong Ge[2], Olivier Pascalis[4], James Tanaka[5], Kang Lee[1]; [1]Dr. Eric Jackman Institute of Child Study, University of Toronto, [2]Department of Psychology, Zhejiang Sci-Tech University, [3]Department of Psychology, University of Delaware, [4]Université Pierre-Mendès-France, [5]Department of Psychology, University of Victoria

Thompson (2010) reported a fat face thin illusion that when next to an inverted face an upright face looks 'fatter' (Figure 1a). Sun et al. (2012) observed that one of the faces need not be inverted for the illusion to emerge: when two identical faces are presented vertically, the face at the bottom appears 'fatter' than the top one (Figure 1b). Neither inverted faces nor clocks induced the illusion. We conducted three experiments probing the role of face contour in producing the fat face illusion (Figure 2). In Experiment 1, line drawing faces were found to induce the illusion, a result suggesting that face contour is important for producing the illusion. In Experiment 2, faces with scrambled internal features and empty faces devoid of internal features also induced the illusion. These data underscore the importance of face contour for producing the illusion by showing that it does not require the normal layout of internal parts or the internal parts in a face per se. In Experiment 3, a subjective contour additionally induced the illusion. In particular, the response rate of "bottom face is fatter" for the normal layout of internal parts (with a subjective contour) was significantly higher than that for a scrambled layout of internal parts (without a subjective contour), suggesting that top-down processing of contour impacts the illusion; however, the magnitude of the illusion induced by subjective contour was significantly lower than that produced by the whole face (with an objective contour), suggesting that bottom-up processing of contour is also involved. The findings indicate that face contour by itself is sufficient to induce the fat face illusion. The illusion is robust regardless of reduction or even elimination of internal part information, and is also present with a subjective contour, implicating a top-down contribution.

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Attention: Spatial and temporal aspects

Saturday, May 11, 2:45 - 6:45 pm

Poster Session, Vista Ballroom

26.536 **Probability Cuing Improves Perceptual Judgments** Britt Anderson[1,2](britt@uwaterloo.ca); [1]Psychology, University of Waterloo, [2]Centre for Theoretical Neuroscience, University of Waterloo

Can probability improve the precision of perceptual judgments? Participants were briefly shown individual tilted gabor patches, and asked to reproduce the tilt. Unbeknownst to the participants some tilt angles were more likely than others; right tilts on the right and left tilts on the left (or vice versa) occured on 80% of the trials. Stimuli tilted in the high probability range were defined as "validly cued." Statistical analysis was with linear mixed effects models treating participant as a random effect. All three experiments demonstrated a reduced magnitude of absolute tilt error for validly cued stimuli, and no bias for orientation judgments. In Experiment 1 we had different participants use either their right or left hand for the matching task in order to assess for a congruency effect (greater effect of probability on the side of the responding hand). The valid cue effect was significant (p = 0.01), but not the congruency effect. This was confirmed by a within subjects manipulation in Experiment 2 where we had participants switch their responding hand midway through the task. Validly cued stimuli were judged more precisely (p = 0.01) and accuracy was not modulated by the side of the responding hand. Experiment 3 flipped the direction of high probability tilts midway through the task. Validly cued stimuli were still judged more precisely (p = 0.003), and a factor coding for the initial direction of high probability tilts was not statistically significant. Additionally, despite instructions emphasizing accuracy, all three experiments showed that validly cued trials were judged more quickly. In summary, using probability to cue an orientation range results in stimuli within that range being judged, on average, more precisely and more quickly. This pattern is similar to that seen with conventional attentional cues, consistent with their having a common mechanism.

Acknowledgement: NSERC

26.537 **Stimulus Value Repetition in Task Switching: An ERP Analysis** Russell Costa[1,3](rcosta@westminstercollege.edu), Jaiya Choles[2], Chrono Nu[1]; [1]Neuroscience Program, Westminster College, [2]Psychology Program, Westminster College, [3]Honors Program, Westminster College

Many accounts of sequential task control posit that when switching attention to a new task, inhibition is applied to aspects of the previously performed task. Such inhibition is most often measured behaviorally in the form of "backward inhibition," a performance cost associated with overcoming previously applied inhibition of a task upon its reactivation. Although much work has focused on how abstract task sets (e.g., color) are inhibited during task alternations, less attention has been devoted to the effects of alternations and repetitions of specific stimulus values (e.g., green) that occur within the task sequences typically employed in task switching designs. In this study we utilized electrophysiological and behavioral measures to compare task set, stimulus-value, and response level processing in a cued task switching paradigm in which participants alternated attention between two visual tasks. Behavioral results from both the color and shape tasks indicated longer response times (RTs) for trials in which the N-1 trial value was repeated (e.g., green to green vs. green to red) in task repetitions and for trials in which the lag-2 value was repeated (e.g., green to triangle to green vs. green to triangle to red) in task switch trials. These RT data are supported by converging evidence from event-related potential (ERP) measures, where larger target-locked P3 amplitudes were consistently observed in the value repeat and the lag-2 value repeat conditions for both tasks. The behavioral effects are in the opposite direction than would be predicted by value-level perceptual priming of the stimulus features and may suggest that specific value-level information is also inhibited with the task set. Taken as a whole, these results suggest that

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factors influencing the perceptual processing of the target stimulus should be taken into account in addition to the more commonly studied cue- and response-dependent processes when measuring task set inhibition.

26.538 The role of prestimulus activity in visual extinction Maren Urner[1,2](maren.urner.09@ucl.ac.uk), Margarita Sarri[3], Tom Manly[4], Jessica Grahn[5], Geraint Rees[1,2], Karl Friston[2]; [1]UCL Institute of Cognitive Neuroscience, London, UK, [2]Wellcome Trust Centre for Neuroimaging, UCL Institute of Neurology, London, UK, [3]UCL Institute of Child Health, London, UK, [4]MRC Cognition and Brain Sciences Unit, Cambridge, UK, [5]Department of Psychology, Brain and Mind Institute, University of Western Ontario, Canada

Patients with visual extinction following right-hemisphere damage sometimes see and sometimes miss stimuli in the left visual field, particularly when stimuli are presented simultaneously to both visual fields. Awareness of left visual field stimuli is associated with increased activity in bilateral parietal and frontal cortex. However, it is unknown why patients see or miss these stimuli. Previous neuroimaging studies in healthy adults show that prestimulus activity biases perceptual decisions, and biases in visual perception can be attributed to fluctuations in prestimulus activity in task relevant brain regions. Here, we used functional MRI to investigate whether prestimulus activity predicted perception in the context of visual extinction following stroke. We measured prestimulus activity in stimulus-responsive cortical areas during an extinction paradigm in a patient with unilateral right parietal damage and visual extinction. This allowed us to compare prestimulus activity on physically identical bilateral trials that either did or did not lead to visual extinction. We found significantly increased activity prior to stimulus presentation in two areas that were also activated by visual stimulation: the left calcarine sulcus and right occipital inferior cortex. Using dynamic causal modelling (DCM) we found that both these differences in prestimulus activity and stimulus evoked responses could be explained by enhanced effective connectivity within and between visual areas, prior to stimulus presentation. Thus, we provide evidence for the idea that differences in ongoing neural activity in visually responsive areas prior to stimulus onset affect awareness in visual extinction, and that these differences are mediated by fluctuations in extrinsic and intrinsic connectivity.

Acknowledgement: Wellcome Trust

26.539 Dissociations and suboptimalities in metacognitive performance due to unbalanced weighting of perceptual evidence can be partially remediated by task instruction and performance feedback Brian Maniscalco[1](brian@psych.columbia.edu), Hakwan Lau[1,2,3]; [1]Department of Psychology, Columbia University, [2]Donders Institute for Brain, Cognition and Behavior, Radboud University Nijmegen, [3]Department of Psychology, UCLA

What mechanisms underlie confidence ratings in perceptual tasks? In a two-choice discrimination task, the observer can potentially acquire two relevant sorts of information: evidence for, and evidence against, making a particular perceptual decision. For instance, deciding that a grating is tilting left rather than right can be driven either by strong evidence for a left tilt or weak evidence for a right tilt. Optimal performance requires perceptual and confidence decisions to take both sources of information into account. However, Zylberberg et al. (2012) found that confidence decisions, but not perceptual decisions, are insensitive to evidence against a selected perceptual choice. We develop a signal detection theory (SDT) model of this insensitivity to negative evidence and show that the model predicts a novel and counterintuitive dissociation. Typically, increases in perceptual task performance are accompanied by increases in metacognitive performance (Galvin et al., 2003; Maniscalco & Lau, 2012). However, if this model is correct, then there should be cases where increasing task performance is accompanied by decreasing metacognitive performance. Empirical tests confirm that this dissociation can be observed in human subjects, providing further support for the hypothesis that confidence ratings are insensitive to negative evidence. This model helps explain why human subjects are often metacognitively suboptimal. It also allowed us to develop new methods for experimentally manipulating subjective confidence without changing perceptual sensitivity. However, these dissociations and suboptimalities in metacognitive performance can be partially remediated in some (but not all) observers if they (1) evaluate task performance by wagering points rather than by rating confidence, and (2) are provided consistent feedback about perceptual and metacognitive performance. This suggests that the blindness of metacognitive mechanisms to negative evidence may not completely reflect a fundamental processing limitation, but rather may partially reflect a poor but correctable usage of decision strategies or cognitive resources.

26.540 The effects of metacognitive awareness on top-down cognitive control. Ai Koizumi[1,2](bellkoizumi@gmail.com), Brian Maniscalco[1], Aaron Apple[3], Xiaoyu Yan[4], Hakwan Lau[1,5]; [1]Department of Psychology, Columbia University, [2]Graduate school of Humanities and Sociology, The University of Tokyo, [3]Department of Psychology, New York University, [4]Department of Philosophy, Columbia University, [5]Donders Institute for Brain, Cognition and Behavior, Radboud University Nijmegen

Our perceptual decisions are often accompanied by metacognitive awareness, expressed by the confidence in the fact that we have made the right perceptual decisions. Since cognitive control seems to require subjective effort, we wondered whether higher perceptual confidence enhances tasks such as inhibitory control and task preparation. One difficulty here was to dissociate the effect of confidence from that of perceptual accuracy, as they often co-vary. Thus, we developed a new method to create sets of gratings whose tilts were equivalent in discriminability, but differed in confidence levels. Experiment 1 assessed inhibitory control with a Go/No-Go paradigm. Gratings with left and right tilts served as Go- and No-Go-signals. Go-signals required speeded key-pressing, whereas No-Go-signals required withholding of key-press. The rate of hit to Go-signals and that of false alarm to No-Go-signals were measured. The results showed that perceiving the signals with higher confidence did not improve inhibitory control. However, higher confidence in a No-Go-trial reduced false alarm rate on the subsequent trials, suggesting that confidence enhances inhibitory control not immediately but with delay. Experiment 2 assessed task preparation with a task-cuing paradigm. The tilts of gratings cued which of the two tasks, phonological or numerical, was to be assigned. These cues were followed by presentation of the task targets (letter/number) with various delays (SOA of 400/600/800ms). The results showed that when the cues were discriminable with higher confidence, RTs to the targets were equivalent across the SOA levels. However, with lower confidence, RTs became faster only with longer SOA. These results suggest that although higher confidence does not enhance task preparation overall, it may modulate the time course of the cued task processing. Overall, these results suggest that metacognitive awareness may only give subtle effects on enhancing cognitive control, despite the general impression that the latter requires subjective conscious effort.

26.541 Complex attention filters for dot contrast derived from a centroid judgment task Howard Yang[1](howary1@uci.edu), Peng Sun[1], Charles Chubb[1], George Sperling[1]; [1]Department of Cognitive Sciences, School of Social Sciences, University of California, Irvine

Purpose: In judging the centroid (center of gravity) of a random cloud of dots, it has previously been determined that subjects can give approximately equal attentional weight only to dots lighter than the background (ignoring dots darker than the background), only to dots darker than the background (ignoring light dots) or to all dots (Drew, Chubb, & Sperling, JOV, 2010). Here we determine whether subjects also can allocate attention to dots in direct proportion to dot contrast. Method: On each trial, either 8 or 16 dots with locations drawn from a bivariate Gaussian distribution with a roved mean were shown for 200ms. Subjects moved a cursor to the centroid of the dot cloud. There were two attention instructions (never intermixed within a day): (1) give equal attentional weight to each dot (ignoring contrast), (2) weight each dot in proportion to its contrast magnitude. On every trial, after the response the true centroid and the subject's response were displayed. Blocks (of 150 trials) with 8 dots of only one polarity (either darker or lighter than the background) were interleaved with 16 dot mixed-polarity blocks. Results: Attention filters were derived from a linear regression model for each condition. When performance stabilized, 8 of 9 subjects showed very clear equal-vs-gradient differences in single polarity conditions. Attention filters derived from dual-polarity tasks show smaller, but still significant equal-vs-gradient differences. For dots of both single and dual-polarity, differences between equal-versus-gradient were larger for dark dots than for light dots. Conclusion: In a task in which far more dots are presented than can be individually processed at a high level, subjects are able to produce attention filters that selectively weight dots either in proportion to contrast magnitude or that ignore contrast magnitude.

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26.542 Attention and spatial scale selection in scene categorization John Brand[1](jo_bra@live.concordia.ca), Aaron Johnson[1]; [1]Department of Psychology, Concordia University

Humans can identify a scene's category within 150 ms. Such efficient categorization has been attributed to the coarse information carried by a scene's low spatial frequencies (LSFs) as opposed to its high spatial frequencies (HSFs; Schyns & Oliva, 1994). However, scene categorization has been

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shown to use the spatial scale that optimizes performance, suggesting a role for attention (Oliva & Schyns, 1997). Here, we address attention's role in scale selection by showing that attention to global or local levels of NAVON stimuli influenced selection of LSFs or HSFs, respectively, in subsequently presented hybrid images (e.g., an image that contains a low-frequency version of one image [a city] and a high-frequency version of another image [a mountain]). Each trial consisted of two displays. The first was a prime display in which participants were instructed to identify a NAVON letter based on its global or local level. The second consisted of a briefly presented hybrid image (30 or 150 ms), in which participants were asked to categorize the hybrid. On 50% of trials, the LSF content of the hybrid corresponded to a natural scene (e.g., beach), whereas on the other 50% of trials the LSF content corresponded to a man-made scene (e.g., city). There were 12 possible hybrid images constructed from four scene categories (2 man-made; 2 natural). We found that when a hybrid image contained a natural and a man-made image, participants preferred to classify the hybrid based on the natural image at short durations, and the man-made image at long durations, irrespective of the NAVON task. However, when the hybrid consisted of two images from the same superordinate category (e.g., both natural), observers preferred to categorize the hybrid based on its LSFs when primed with the global NAVON task, and its HSFs when primed with the local NAVON task.

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26.543 **Enumeration of Illusory Contour Figures** Natasha Dienes[1](n-dienes@uoguelph.ca), Lana Trick[1]; [1]Department of Psychology, University of Guelph

Every day we encounter objects that are partially obscured by shadows or other objects. We can study how our visual system processes these items by creating objects which do not have a real contour (i.e., a solid line) completely surrounding them. This project used enumeration (determining the number of objects present) to study the way that illusory contour figures are processed. The processing of illusory contour objects has previously been studied using a visual search task (Li, Cave & Wolfe, 2008). Li, et al. (2008) found that line-end illusory contour figures (figures that are induced through the particular way lines end around the "object") pop out in visual search. Because objects that pop out in search are usually subitized (fast, accurate and effortless enumeration of a small quantity of objects), it was hypothesized that line-end illusory contour figures would be subitized both when they were presented only as targets (simple enumeration task) and when they were presented with distractors (selective enumeration task). The simple enumeration task required participants to enumerate 1-9 vertical line-end illusory contour rectangles or real contour rectangles presented in conjunction with the line-end inducers. The selective enumeration task was the same expect for the addition of 4 or 8 horizontal distractors of the same figure type. The results of these two enumeration tasks revealed that line-end illusory contour figures can be subitized when they are presented alone, but not when they are presented with distractors. These results may be due to differences in task demands which can be explained by Pylyshyn's (1988) FINST theory.

Acknowledgement: NSERC

26.544 **Blink Inhibition and Entrainment** Jack Dahlin[1](jdahlin13@gmail.com), Emily Bach[2], Flip Phillips[2]; [1]Burnt Hills-Ballston Lake High School, [2]Skidmore College, Neuroscience & Psychology

From a physiological viewpoint, blinking is used to keep objects out of the eye and to hydrate the eyes. When blinking occurs the visual cortex and the prefrontal and parietal cortices show a decrease in activity for approximately 400 ms. Recent research shows that, due to this loss of visual information, participants may search for appropriate moments to blink or entrain their blinks. Furthermore, this research shows that participants, while watching videos, also inhibited their blinks within the video. A similar study also shows that people will look for a common point in which to blink, or an entrainment point. In this work we test blink entrainment between the eyes of an actor in a video and that of the participant. Subjects watched a close up video with variable story lines, with audio, video, or audio and visual components. We hypothesized that blink entrainment would be highest during the audio-visual stimuli and in stimuli that had the steadiest blink tempo. We found blink entrainment to increase across the three conditions (audio, visual, and audio visual) with entrainment being highest in the audio visual condition with a entrainment of Qt of .5. In addition, participants were near even to slightly lagging to the videos blinks with the most lag in the audio visual section with a qt of .01. In addition we found hints of blink entrainment in non blink events such as those in the Heider Simmel Test. Viewers presented with audio and visual conditions will entrain their blinks more highly and the entrainment lags in the conditions suggest deeper cognitive processes.

26.545 **Consciousness During the Attentional Blink: Partial or All-or-None?** James Elliott[1,2](elliott@psych.ucsb.edu), Benjamin Baird[1], Barry Giesbrecht[1,2]; [1]Department of Psychological and Brain Sciences, UCSB, [2]Institute for Collaborative Biotechnologies, UCSB

Previous work has suggested that, at least during the Attentional Blink (AB), consciousness of an object is an all-or-none phenomenon (Sergent & Dehaene, 2004). However, the partial awareness hypothesis suggests that this all-or-none property of consciousness should be attributed to consciousness of features (Kouider et al., 2010). The all-or-none hypothesis clearly predicts that when one feature is correctly identified, all other features of the object should also be correctly identified. On the other hand, the partial awareness hypothesis predicts that representations of specific features of objects may reach conscious access independently of each other. We tested these competing predictions in two experiments. In experiment 1, participants (n=16) searched an RSVP for two targets (T1 and T2), and the time between the two targets was manipulated. The T2 task consisted of reporting both identity and color (red, green, or blue). When AB magnitude (ABM; lag 9 - lag 2) was computed using T2 report accuracy conditionalized on correct report of one feature, there was still a significant AB for the other feature (color|identity: ABM=.16, p=.009; identity|color: ABM=.51, p<.001). In experiment 2 (n = 23), the number of potential T2 identity responses was matched to the number of color responses (identity: H,S, or X; color: red, green, or blue). This experiment also included a single target control in which T1 was removed from the stream and participants only reported T2 identity and color. In the dual task condition, when ABM was computed using T2 report accuracy conditionalized on correct report of one feature, an AB was observed for the other feature (color|identity: ABM=.27, p<.001; identity|color: ABM=.22, p<.001). The results of these two experiments support the partial awareness hypothesis, showing that, at least during the AB, there can be a dissociation between consciousness of different features of the same object.

Acknowledgement: Yoga Science Foundation

26.546 **Interdependencies between attentional priming and perceptual interpretation of ambiguous stimuli** Arni Kristjansson[1](ak@hi.is), Sigurbjorg Egilsdottir[1], Gabriela Gilmour[2], Omar Johannesson[1], Inga M Olafsdottir[1], Jan Brascamp[3]; [1]School of Health Sciences, University of Iceland, [2]McGill University, [3]Helmholtz Institute, Utrecht University

Attentional selection and the perception of ambiguous visual input are both strongly influenced by past events. History dependencies in attention and in perception are, however normally considered unrelated and studied in separate fields. Here we investigate their relation. During 'ambiguous trials' observers viewed a briefly-presented ambiguous Necker cube, which has two possible perceptual interpretations. On 'search trials' observers searched among unambiguous cubes that each represented either of these interpretations, the target being an oddball that represented a different interpretation than the rest. When presenting consecutive ambiguous trials, perception on a given trial often conformed to earlier perception, an established example of percept priming. Similarly established, responses on consecutive search trials became faster when target identity repeated than when it changed, demonstrating attentional priming. Surprisingly, intermixing ambiguous trials and search trials revealed a mutual interaction: search responses were faster to targets representing the interpretation perceived on previous ambiguous trials, and perception during ambiguous trials tended to conform to the target on preceding search trials. For individual observers, the magnitude of the effect of ambiguous trials on subsequent search trials significantly predicted effect magnitude of search upon judgment of ambiguous stimuli. Moreover, the influence of perception upon subsequent search largely depended on perceptual ambiguity, since simple viewing of unambiguous cubes only minimally affected subsequent search speeds. Our results suggest a partial identity between attention priming and perception priming, thus bridging two hitherto unrelated fields of vision science. Beyond history dependencies, our results suggest that becoming aware of one visual interpretation while alternative interpretations are not perceived may be fundamentally similar to paying attention to some parts of visual input while ignoring others, reflecting the operation of overlapping visual and attentional mechanisms.

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26.547 Heritability of reflexive attentional orienting induced by social cues Li Wang[1](wangli@psych.ac.cn), Ying Wang[1], Qian Xu[1], Dong Liu[1], Yi Jiang[1]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Psychology, Chinese Academy of Sciences

Social attention is crucial for adaptive social behaviors and nonverbal communications in humans, and the malfunction of which has been implicated in autism, a highly genetic neurodevelopmental disorder marked by striking social deficits. The present study investigated the genetic contribution to individual variation in social attention. Using a classical twin design, the heritability of reflexive attentional orienting effects induced by two distinctly different social cues (i.e., eye gaze and biological motion walking direction) was examined. Results revealed reliable genetic influences on reflexive social attention of both cues, and further analyses of the effect concordance for twin pair members across the two types of cues yielded significant positive correspondence for MZ twins (with identical genes) but not for DZ twins (sharing 50% genes), indicating that common genetic factors may be involved in driving the attentional effects induced by these two different forms of social cues. Moreover, no evidence of heritability was observed when nonsocial cues (i.e., arrows) were employed in the control experiment. These findings together suggest the role of social attention in seeking the potential endophenotypes for autism and encourage the identification of "social attention genes".

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26.548 Viewing Cultural Scenery Afford Culture-Specific Visual Attention Yoshiyuki Ueda[1](ueda@educ.kyoto-u.ac.jp), Asuka Komiya[2]; [1]Kokoro Research Center, Kyoto University, [2]Graduate School of Humanities, Kobe University

Although many studies have found the existence of cultural differences in higher-order cognitive processing, such as decision making and guess, whether cultural differences exist in processing of a more fundamental nature, such as visual attention and scene perception, is still controversial (e.g., Chua et al., 2005; Rayner et al., 2007; Nisbett et al., 2001). Among many aspects in culture such as ways of communication and language, Miyamoto et al. (2006) indicated one possibility that differences of landscapes explain the origin of cultural differences. In the present study, we examined the influence of the cultural scenery images on how to perceive cultural-independent general sceneries. In the experiment, Japanese participants were asked to see scenery images and rate the degree to which they like them. During the task, eye movements of the participants were measured. In the first block, culturally neutral scenery (e.g., a dog in a park) was presented and participant's eye movements were measured as baseline. In the following three blocks, Japanese typical sceneries were presented to some participants and American typical sceneries were presented to other participants. Eye movements during these blocks indicated how to perceive cultural typical sceneries. Then in the last four blocks, the culturally neutral sceneries were presented every fourth trial, following three cultural sceneries, which were presented to prevent weakening of their exposure. The results showed that participants were more likely to move their eyes within a broader area when viewing Japanese sceneries than they were when viewing American sceneries. Moreover, a correspondent pattern was observed even when viewing culturally neutral sceneries. When viewing sceneries which contain single object, fixations were more likely to be distributed after seeing Japanese sceneries. These differences afforded by the cultural scenery images lead to different visual attention processing among cultures.

26.549 What you see is what you get: Webcam viewing angle influences social coordination Laura Thomas[1](laura.e.thomas@ndsu.edu), Daniel Pemstein[2]; [1]Department of Psychology, North Dakota State University, [2]Department of Criminal Justice and Political Science, North Dakota State University

Increasingly, people communicate remotely using video chat programs such as Skype. The constrained viewing angles these programs afford limit and alter the visual information available to users, potentially influencing perception and cognition. We examined how camera placement affected participants' performance in a joint decision-making task. Participants played a two-person game that presented each player with two options. Players received higher payoffs when they coordinated around the same option than when they failed to coordinate, but each player's largest payoff was associated with coordination around a different option. Participants sat in separate rooms in front of identical computer monitors—one in which the webcam rested above the center of the monitor and the other in which the webcam rested the same distance below the center of the monitor—and, using Skype, discussed the game for two minutes. Following the Skype call, each participant independently chose one of the two available options. Although the participants reported being unaware of any differences in viewing angle, we found that participants who sat in front of the monitor with the low webcam received a larger payoff almost twice as often as participants who sat in front of the monitor with the high webcam ($p<.05$). Participants in the high webcam condition were more likely to defer to a partner they looked up to, making coordination choices that rewarded their partner more than themselves. When participants instead played a game in which the camera viewing angles were the same across monitors, no such inequalities were apparent in their choices. These results demonstrate that a subtle perceptual cue—viewing angle—affects higher-order decision-making processes. They also suggest that the viewing conditions during video chat may trigger embodied associations of size or height.

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26.550 Examining the influence of video game training on spatial cognition and outgroup bias Leslie McCuller[1](lesliemcculler@yahoo.com), Michael Dodd[1]; [1]Department of Psychology, University of Nebraska - Lincoln

Common coding theory indicates that we covertly replicate all perceived and imagined actions (Chandrasekharan et al. 2010) due to a blurring of first and third person views, which are attributed processes in the motor cortex (Ezel et al. 2008; Fadiga et al. 2000). When players see the actions of an avatar on screen they covertly replicate them from the perspective of the avatar (Thirioux et. al 2009), and when the players control the avatar and see it execute their actions it results in a mere exposure effect in which the player forms an unconscious preference for the avatar (Topolinski & Strack, 2009; Beilock & Holt, 2007). Socially, motor activation is implicated in both social biases and preferences (Dijksterhuis, 2005) leading people to unconsciously prefer people who mirror their actions. The purpose of the present study, therefore, was to determine whether baseline levels of racism and sexism could be reduced through video game training. Participants complete a number of pretest measures tapping into racism and sexism, following which they play Kinect Adventures (for the Xbox Kinect which allows for a nearly 1:1 mapping of action between the player and the onscreen avatar) with an avatar that is either an in-group member (e.g., looks like the game player) or an out-group member (does not look like the game player). Following the video game session, participants complete identical post-test measures to determine whether the player has formed an unconscious preference for the avatar based on its replication of the player's actions. In both experiments we find evidence for a change in attitude (albeit brief) following video game training. These findings have implications in a number of applied areas in addition to providing further insight into common theory.

Acknowledgement: University of Nebraska - Lincoln Research Council (Faculty Seed Grant)

26.551 The dynamics of the focus of attention depend on what the observer is reading Saeideh Ghahghaei[1](saeideh@ski.org), Karina Linnell[2]; [1]Goldsmiths, University of London Smith-Kettlewell Eye Research Institute, [2]Goldsmiths, University of London

We measured the spatio-temporal distribution of attention during active reading. We examined three variables that are known to affect the processing load of a word: word frequency (high- or low-frequency), whether valid visual information for the word was available before or only after it was fixated (valid or invalid preview, respectively) and the reading task. Using a novel dual-task technique, we probed the focus of attention (6 characters to the left or right of the gaze location) early (temporal offsets of 10 or 40 ms) during the first fixation on target words. For the primary task, participants read either sentences or strings of random words. For reading random words, preview was valid (where a word's letters were always exposed) for one group of participants and was invalid (where letters in a word were masked and only exposed when the word was fixated) for another group. For reading sentences, preview was valid. For the secondary task, participants made an unspeeded 2-AFC concerning the orientation of the probe, a tilted line briefly superimposed on a character. Discrimination of probe orientation provided the measure of attention. For all task/preview manipulations, fixation durations were longer on low- than high-frequency target words, confirming that reading occurred. The focus of attention was skewed towards the direction of reading (right in English texts) and expanded over time. Attention was more focused on the gaze location for low- than high-frequency words when preview was valid. There was no effect of frequency on the focus of attention when preview was invalid.

The results (i) show that the focus of attention in reading is dynamic and is affected by the moment-to-moment processing load of the word, and (ii) are beneficial to models of eye movement control in reading and in general.

26.552 **Publication and verification bias in vision science** Gregory Francis[1](gfrancis@purdue.edu); [1]Psychological Sciences, Purdue University

With cases of fraud, unbelievable discoveries (such as people being influenced by future events), key experimental findings that fail to replicate, and evidence that researchers use questionable research practices to produce significant findings, psychological science faces serious questions about whether the field can be trusted to produce valid scientific work. In an effort to reinstate the integrity of reported findings in psychological science, many researchers emphasize the importance empirical replication. Such an approach relies on the belief that true phenomena can be successfully demonstrated in well-designed experiments. Indeed, the ability to reliably reproduce an experimental outcome is widely considered the gold standard of scientific investigations. Unfortunately, this view is incorrect; and misunderstandings about replication contribute to the conflicts in psychological science. Because experimental effects in psychology are measured by statistics, there should almost always be some variability in the reported outcomes. An absence of such variability actually indicates that experimental replications are invalid, perhaps because of a publication bias to suppress contrary findings or because of a verification bias that utilizes improper methods to favor a desired experimental result. Such experimental results should be considered "too good to be true." Vision science is not immune to these issues, and overly successful replication rates are easily identified within the field; some representative examples will be presented. Although not a cure all for scientific investigations, a return to the principles of psychophysical methods would greatly alleviate these kinds of biases and help insure confidence in the validity of scientific reports.

26.553 **Attentional bias for body-related visual stimuli in eating disorder tendency.** Moe Nagahata[1], Hiroshi Ishikane[1]; [1]Department of Psychology, Graduate School of Humanities, Senshu University

It has been suggested that patients with eating disorders have a distorted body image and show an attentional bias for information related to the human body. However, little is known about the relationship between attentional properties and eating behaviors of healthy volunteers. Therefore, attentional bias for body-related information in female undergraduate participants, without eating disorders that volunteered was investigated. First, the Eating Disorders Inventory (EDI-91), a questionnaire assessing the eating disorder tendency was administered to the participants. Then, we conducted an experiment using the visual search paradigm. Participants were shown stimuli consisting of pictures of the human body and neutral stimuli not related to the body in a target, or a distractor condition using a computer display. Either four pictures in the same category (target absent trial), or three pictures in the same and one in a different category (target present trial) were presented simultaneously. Participants' judged whether the four presented stimuli were the same, or included one stimulus of a different category by pressing a key. Their reaction times (RT) and electroencephalograms were recorded. Results indicated that the RTs were faster in the human body condition than in the neutral target and neutral distractor condition. Moreover, participants with high body dissatisfaction (BD) as measured by EDI-91 subscale detected human body related stimuli faster than neutral stimuli. Furthermore, the amplitude of N2 event-related potential correlated with BD in the body stimuli distractor condition. These results suggest that body stimuli facilitate an attention shift, and therefore they might cost few attentional resources in participants with a high eating disorder tendency. This attentional bias correlates with BD in various aspects of the eating disorder tendency and occurs in several levels of cognition.

Acknowledgement: This study was supported in part by a grant of Strategic Research Foundation Grant-aided Project for Private Universities from MEXT Japan (2011-2015 S1101013).

3D perception: Neural mechanisms and models

Saturday, May 11, 2:45 - 6:45 pm

Poster Session, Vista Ballroom

26.554 **Decomposing intensity gradients into information about shape and material** Pascal Barla[1](pascal.barla@inria.fr), Romain Vergne[2], Roland Fleming[3]; [1]Inria Bordeaux, [2]Inria Rhône-Alpes, [3]Justus-Liebig-Universität Giessen

Recent work has shown that the perception of 3D shapes, material properties and illumination are inter-dependent, although for practical reasons, each set of experiments has probed these three causal factors independently. Most of these studies share a common observation though: that variations in image intensity (both their magnitude and direction) play a central role in estimating the physical properties of objects and illumination. Our aim is to separate retinal image intensity gradients into contributions of different shape and material properties, through a theoretical analysis of image formation. We find that gradients can be understood as the sum of three terms: variations of surface depth conveyed through surface-varying reflectance and near-field illumination effects (shadows and inter-reflections); variations of surface orientation conveyed through reflections and far-field lighting effects; and variations of surface micro-structures conveyed through anisotropic reflections. We believe our image gradient decomposition constitutes a solid and novel basis for perceptual inquiry. We first illustrate each of these terms with synthetic 3D scenes rendered with global illumination. We then show that it is possible to mimic the visual appearance of shading and reflections directly in the image, by distorting patterns in 2D. Finally, we discuss the consistency of our mathematical relations with observations drawn by recent perceptual experiments, including the perception of shape from specular reflections and texture. In particular, we show that the analysis can correctly predict certain specific illusions of both shape and material.

Acknowledgement: PRISM Marie-Curie ITN

26.555 **Probabilistic Interpretation of Depth in Line Drawings due to T-junctions** Seha Kim[1,2](sehakim@eden.rutgers.edu), Manish Singh[1,2], Jacob Feldman[1,2]; [1]Department of Psychology, Rutgers University-New Brunswick, [2]Rutgers University Center for Cognitive Science

Line drawings can effectively convey the 3D shape of objects despite the absence of most conventional depth cues. The 3D percept can be especially clear when drawings include internal contours and T-junctions as well as outer bounding contours. Early work that focused on cataloguing and analyzing various junction types (Huffman, 1971; Clowes, 1971; Waltz, 1972; Mackworth, 1973; Charkravarty, 1979; Malik, 1987) was limited by a dependence on deterministic junction interpretation rules. We revisit the study of T-junctions and related contour cues to depth, but now in a probabilistic framework. We hypothesized that the interpretation of surface shape in line drawings including T-junctions involves a process of probabilistic estimation of depth, based on both local and non-local cues. This formulation incorporates default (traditional) depth interpretations of junctions into a likelihood function, and can thus accommodate non-default (non-traditional) interpretations with other constraints when they are required to maximize the posterior. Moreover, the probabilistic framework allows us to quantitatively model the contribution of local and non-local depth cues, including the "propagation" of the influence of a T-junction at points various distances from it. We measured depth order for pairs of points (Koenderink et al., 1996; Koenderink et al., 2011) inside line drawings constructed so as to modulate the presence and location of critical depth cues. Observers reported the depth order of the dots, with the responses indicating the apparent 3D surface structure of the inferred shape. We found systematic effects of the location of dots with respect to the T-junctions, with systematic changes in the way depth order was interpreted as a result of the local and global structure of the contours. The findings shed light on how the local depth information drawn from T-junctions propagates and interacts with cues derived from other contours to yield a percept of the 3D surface.

Acknowledgement: NSF IGERT DGE 0549115, NIH(NEI) EY021494

26.556 **The brain's 'superformula': perceptual reconstruction of complex shape spaces** Haemy Lee[1](hello-stranger@nate.com), Christian Wallraven[1]; [1]Department of Brain and Cognitive Engineering, Korea University

Human are experts at visual processing of shape. Various shape properties, such as curvature, aspect ratio, or symmetry seem readily accessible to the visual system after only a short glance. Previous research has proposed that shape knowledge can be well described within a (metric) perceptual space. In such a space distances between different shapes encode their dissimilarity, and these distances also capture relevant physical properties of shape. Recently, an interesting mathematical description of shape has been introduced that is able to generate a large variety of three-dimensional shapes with a few parameters (the so-called 'superformula'). Here, we test how well the mathematical space defined by the 'superformula' can be reconstructed by visual perception. The experiment used a three-dimensional subspace of the 'superformula' parameter space, which generated 13 objects varying in shape in a highly complex fashion. The subspace was generated in the form of a cross lying obliquely in the subspace. A total of 15 participants were asked to judge similarities between

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all possible object-pairs (a total of 91 trials). The experiment employed an active exploration paradigm in which participants were allowed to rotate objects on the screen for maximum performance. Two objects were presented successively for 5sec each with an ISI of 1sec. Similarity between objects was rated on a seven-point Likert-type scale. Similarity ratings were averaged across participants to obtain a group similarity matrix, which was subjected to metric multidimensional scaling (MDS). We found that three dimensions were able to sufficiently explain the similarity ratings. The underlying topology of the 'superformula' parameter space was recovered very well overall, with highly consistent ordering of stimuli along the original parameter-axes of the cross. Our results show that the visual system is highly efficient at extracting shape structure and point towards the usefulness of the 'superformula' framework in modeling shape knowledge.

Acknowledgement: This research was supported by the WCU (World Class University) program through the National Research Foundation of Korea funded by the Ministry of Education, Science and Technology (R31-2008-000-10008-0).

26.557 **Establishing 3D symmetry correspondence in asymmetrical perspective images** Yunfeng Li[1](li135@purdue.edu), Zygmunt Pizlo[1]; [1]Department of Psychology, Purdue University

Symmetry correspondence is analogous to stereo and motion correspondence problems. Unlike the other two, symmetry correspondence was completely ignored in prior research. The importance of this problem is related to the fact that 3D symmetry of objects is the most fundamental a priori constraint used by the human visual system in recovering 3D shapes of the objects (Li et al., 2009, 2011). 3D mirror symmetry is easy to verify in 3D representations: pairs of mirror symmetrical points form parallel lines segments that are bisected by the symmetry plane. However, a 2D perspective image of a 3D mirror-symmetrical shape is almost never symmetrical. How is the visual system able to establish 3D symmetry correspondence in 2D asymmetrical images? Similarly to the other two correspondence problems, solving symmetry correspondence in an image is an ill-posed problem because (1) a given edge can have many possible correspondences; (2) any two edges can have infinitely many spurious 3D symmetrical interpretations (Sawada et al., 2011). In this study, we show which a priori constraints have to be used in order to correctly solve the symmetry correspondence problem. The solution begins with solving figure-ground organization (FGO) problem in 3D and 2D representations. This is done based on coarse information provided by a pair of images obtained by a stereoscopic camera. The 3D FGO is used to estimate the plane of symmetry of the 3D object, assuming that this plane is orthogonal to the ground plane, and the 2D vanishing point representing the 3D symmetry in perspective images. We then extract edges within regions of the 2D image representing individual objects (figures). Finally, we detect pairs of symmetric curves by evaluating their (i) relation to the vanishing point, (ii) relative 2D orientation and (ii) relative distance. We will illustrate this model with real images of real objects.

26.558 **Extracting shapes from objects** Yun Shi[1](shixiaofish@yahoo.com), Yunfeng Li[1], Zygmunt Pizlo[1]; [1]Department of Psychological Sciences, Purdue University

Shape is one of the most important characteristics of objects, which allows us to identify them and recognize their functions. The conventional view has been that all objects have shapes, although there has been no agreement about what shape is. Here we propose a new definition of shape according to which shape refers to all spatial regularities of the object. By regularities we mean self-similarities or redundancies. This view of shape is rooted in Hochberg & McAlister's (1953), as well as Attneave's (1954) approaches, and has recently been formalized by Feldman and Singh (2005). This latter formalism allows one to measure the description length (DL) of a curve, which represents the information content (complexity) of the curve. In order to switch from "describing a curve" to "extracting the curve's shape", we modify the method proposed by Feldman and Singh in two ways. First, we define the complexity of a curve as the sum of the complexity of a regular representation η of the curve (the curve's shape), and the complexity of noise, which is the proportion of the original curve not captured by η. The shape η is the one that minimizes the total description length of the curve as represented by the sum of these two components. Second, our approach naturally allows one to include conventional symmetries such as mirror, rotational and translational and to treat them the same way as all other spatial regularities. In a sense, this second part of our theory resembles Leeuwenberg's (1971) ideas behind his Structural Information Theory. These two elaborations are the key to generalizing the new definition of shape to 3D natural objects.

Acknowledgement: National Science Foundation

26.559 **Categorizing three-dimensional natural scenes** Zhiyong Yang[1,2,3](zhyang@georgiahealth.edu), Xiaoyuan Zhu[1], Julian Nussbaum[2,3]; [1]Brain and Behavior Discovery Institute, Georgia Health Sciences University, Augusta, Georgia, [2]Culver Vision Discovery Institute, Georgia Health Sciences University, Augusta, Georgia, [3]Department of Ophthalmology, Georgia Health Sciences University, Augusta, Georgia

Natural visual scenes consist of objects of various physical properties that are arranged in three-dimensional (3D) space in a variety of ways. The higher-order statistics of this environment we interact with daily is crucial for our understanding of 3D vision, space navigation, space memory, and the underlying neural mechanisms. We acquired a database of natural scenes that include both distance and luminance information. To examine the statistics of 3D natural scenes, we transformed the range images into XYZ images in the Cartesian coordinate and sampled a large number of patches from the XYZ images. We obtained the independent components (ICs) of the sampled patches, fitted 3D surfaces to the ICs, and examined the probability distribution of distances, orientations, and curvatures of the fitted 3D ICs. Using these 3D ICs, we compiled a large set of 3D natural scene structures (NSSs), i.e., spatial concatenations of 3D ICs, and used them to categorize 3D natural scenes. To this end, we cropped 1,000 patches from the large-scale 3D natural scenes and divided them evenly into 10 classes. We then calculated the information content of each 3D NSS, i.e., the rate at which the 3D scenes in the training set were recognized based on the NSS, and selected a set of NSSs that had high information content for each class of 3D scenes. Finally, we used the selected 3D NSSs to categorize natural scenes. We found that: 1) this model achieved a high categorization performance; 2) NSS are more efficient than simple features in conveying information about scene identities and scene categories; and 3) spatial concatenations of individual NSSs and multiple NSSs are important for 3D scene categorization. Thus, we concluded that the 3D NSSs obtained here are a useful set of code words for encoding complex 3D natural scenes.

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26.560 **The neural basis of 3D rotation sensitivity from self-generated Optic Flow: a Transcranial Magnetic Stimulation Study** Giovanni Mancuso[1,2](giovanni.mancuso@iit.it), Carlo Fantoni[1,3], Fulvio Domini[1,4], Lorella Battelli[1,5]; [1]Italian Institute of Technology, Neuroscience and Cognitive Systems, Rovereto, Italy , [2]CIMeC, Center for Mind/Brain Sciences, University of Trento, Rovereto, Italy, [3]Department of Life Sciences, Psychology Unit "Gaetano Kanizsa", University of Trieste, Italy, [4]Department of Cognitive, Linguistic & Psychological Sciences, Brown University, [5]Berenson-Allen Center for Noninvasive Brain Stimulation, Beth Israel Deaconess Medical Center, Harvard Medical School

A stationary surface slanted around the vertical axis and observed during a head translation appears to be stationary during monocular, but not binocular viewing when the same image is projected to the two eyes (null disparity). This effect is likely caused by the perceptual interpretation of the optic flow affected by the null disparity information, rather than by extra-retinal signals coming from vergence and accommodation, which instead should lead to an unbiased perception (Fantoni, Domini & Caudek 2010). Here, we investigated the neural basis of this phenomenon with a rotation-detection task during active binocular and monocular viewing before and after offline inhibitory rTMS over early visual areas V2/V3 and the Middle Temporal area (hMT). At baseline subjects reported a rotating object significantly more often in the binocular relative to the monocular viewing condition. Stimulation overV2/V3 caused a reduction of the response bias and a general improvement of the sensitivity in the binocular viewing condition only. These findings were consistent with: I) a disruption of disparity information conflicting with motion and II) a residual effect of binocular summation occurring earlier in the visual hierarchy. Interestingly, stimulation of hMT led to a selective impairment of performance in the monocular viewing condition. Contrary to V2/V3 stimulation, binocular viewing condition was not affected by hMT stimulation. This might indicate that any potential performance gain due to the inhibition of hMT disparity neurons was constrained by the performance impairment due to the inhibition of hMT motion-sensitive neurons. Overall, the results suggest that: (1) the perception of 3D surfaces during active vision is likely mediated by the activity of cortical areas involved in the processing of retinal but not extra-retinal signals; (2) both hMT and V2/V3 are critically involved in the encoding and integration of motion and disparity signals generated during active vision.

Sunday Morning Talks

Motion: Neural mechanisms and models

Sunday, May 12, 8:15 - 9:45 am

Talk Session, Royal Ballroom 1-3

Moderator: Richard Krauzlis

31.11, *8:15 am*

Propagation of local adaptation is insufficient to generate repulsive motion aftereffects Alan L. F. Lee[1](alanlee@ucla.edu), Hongjing Lu[1,2]; [1]Department of Psychology, University of California, Los Angeles, [2]Department of Statistics, University of California, Los Angeles

A hallmark of motion adaptation is the repulsion effect: adapting to a particular direction causes the perceived direction of test motions to be shifted away from the adapting direction. However, it is unclear at which level(s) of hierarchical motion processing such repulsive aftereffects originate. In this study, we dissociated local versus global motion adaptation, and examined the processing underlying repulsion effects in motion adaptation. Randomly-oriented, multiple-Gabor motion stimuli (Amano et al., 2009) were used as the adapting and test stimuli. To delineate local and global motion adaptation, four conditions were included. (1) In the adapt-both condition, adaptation was induced at both local and global levels. The adapting stimulus contained only one coherent global direction, and motion aftereffect (MAE) was measured at adapted locations. (2) In the global-only condition, the MAE was measured at non-adapted locations after adapting to one coherent global motion direction. (3) In the local-only condition, the adapting stimulus included five global directions so that observers could not perceive any coherent motion (thereby effectively eliminating adaptation at global level), and MAE was measured at adapted locations. (4) In the adapt-neither condition, the adapting stimulus included five directions and MAE was tested at non-adapted locations. For all these four conditions, we measured the strength of dynamic MAE using the coherence-nullification method in Experiment 1, and measured the direction repulsion effect in Experiment 2. In Experiment 1, all conditions, except the adapt-neither control, yielded a significant MAE. In Experiment 2, direction repulsion effect was strong when the global level was adapted (i.e., in the adapt-both and global-only conditions), but the effect diminished in the absence of global adaptation (i.e., in the local-only and the adapt-neither conditions). These results suggest that, although the propagation of local motion adaptation can produce a perceptual aftereffect, it is insufficient to generate a directional repulsion.

Acknowledgement: NSF BCS-0843880

31.12, *8:30 am*

Bayesian observer model of the motion induced position shift

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, Rochester, [2]Department of Ophthalmology, University of Rochester

Numerous perceptual demonstrations show that motion influences the spatial coding of object position. For example, the perceived position of a static object is shifted in the direction of motion contained within the object. We postulate that this motion induced position shift (MIPS) results from a process of statistical inference in which position and motion estimates are derived by integrating noisy sensory inputs with the prediction of a forward model that reflects natural dynamics. The model predicts a broad range of known MIPS characteristics, including MIPS' dependency on stimulus speed and position uncertainty and the asymptotic increase in MIPS with increasing stimulus duration. The model also predicts a novel visual illusion. To confirm this prediction, we presented translational motion (low-pass filtered white noise moving at 7.8°/s) within a stationary Gaussian envelope (s = 0.5°). Crucially, the direction of translation changed at a constant and relatively slow rate (0.72 Hz). Subjects perceive this stimulus as moving along a circular path in a way that its perceived motion conspicuously lags behind the direction of the motion within the object. To quantify this illusion, subjects adjusted the radius and phase of a circularly moving comparison disk to match the perceived motion path of the test stimulus. We found that the matching radius of motion (i.e., perceived illusory rotation) gradually increased from 0.6° to 1.0° as the eccentricity increased from 7.9° to 22.6°. Notably, the phase of the perceived object motion lagged behind the motion in the test stimulus by almost a quarter of the cycle, increasing from 73° to 82° as eccentricity increased. These results are consistent with the behavior of a Kalman filter that integrates sensory signals over time to estimate the evolving position and motion of objects. The model provides a unifying account of perceptual interactions between motion and position signals.

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31.13, *8:45 am*

Motion-induced position shift in stereoscopic and dichoptic viewing Rumi Hisakata[1](hisakata@fechner.c.u-tokyo.ac.jp), Ikuya Murakami[1]; [1]Dept. of Life Sciences, University of Tokyo

The static envelope of a Gabor patch with a moving carrier appears shifted in the direction of the carrier motion (De Valois & De Valois, 1991). Although several motion processing stages from low to high might contribute to this phenomenon of motion-induced position shift (MIPS), the relationship among the MIPS, binocular disparity, and dichoptically presented carriers, is unclear. To elucidate it, we first investigated the disparity tuning of the MIPS by manipulating the relative disparity between the carrier and envelope. Both a horizontally moving sinusoidal grating inside a Gaussian envelope and the envelope itself had several absolute disparities. The background was filled with static random noise. Two such patches were shown above and below the fixation point, and we determined the point of subjective alignment as the illusion strength. The MIPS occurred even when the moving carrier had radically different disparities than the envelope's, suggesting that the underlying mechanism of the phenomenon can exist at a monocular visual stage. To confirm this suggestion, in the next experiment we examined whether the depth perception of the envelope was induced by illusory position shifts in interocularly opposite directions. Two Gabor patches moving in opposite directions between the two eyes were presented at the same retinal region. Visible parts of the Gabor patches were horizontally interleaved between the two eyes to exclude depth perception due to an interocular velocity difference between corresponding retinal regions. We found that the depth perception of the binocularly fused envelope of the Gabor patch was biased by the illusory crossed or uncrossed disparity that was expected to occur under the assumption of the MIPS occurrence at a monocular stage. The depth of a similar patch with a hard edged envelope was less biased. We conclude that the position shift is already represented at a monocular processing stage.

Acknowledgement: This study was supported by the JSPS Funding Program NEXT (LZ004).

31.14, *9:00 am*

Optimal retinal speed estimation in natural image movies Johannes Burge[1](jburge@mail.cps.utexas.edu), Wilson Geisler[1]; [1]Center for Perceptual Systems, University of Texas, Austin

The neural computations underlying selective perceptual invariance are enormously complex. Many studies of neural encoding-decoding assume neurons with invariant tuning functions. Here, we show how construct neurons that are largely invariant to irrelevant natural image variation. We do so by applying a task-specific encoding-decoding framework that simultaneously specifies how to encode and decode task-relevant information from the retinal image. We use the framework to estimate retinal image speed from photoreceptor responses to natural image movies. The movies were consistent with local translation relative to fronto-parallel and slanted surfaces. The distribution of slants in natural scenes was well-approximated by the distribution of slants in the analysis. The space-time receptive fields (RFs) that optimally encode information relevant for estimating speed are direction selective but, interestingly, they are not speed-tuned. Appropriate non-linear combination of the RF responses yields a new population of neurons that are speed tuned and are (largely) invariant to irrelevant stimulus dimensions. These neurons represent the log-likelihood (LL) of speed and have tuning curves that are approximately log-Gaussian in shape. MAP decoding yields unbiased speed estimates over a wide range (-8 to 8 deg/sec). The optimal space-time RFs and speed-tuned LL neurons share many properties with neurons in cortex. Most motion sensitive neurons in V1 and MT are direction but not speed selective whereas ~25% of V1 and MT neurons are speed tuned (Priebe, Lisberger, Movshon, 2006). Cortical speed-tuned neurons have tuning curves that are log-Gaussian in shape (Nover, Anderson, DeAngelis, 2005). Critically, the optimal space-time RFs and speed-tuned neurons from our analysis were not arbitrarily chosen to match the properties of neurophysiological RFs. Rather, they emerge from a task-specific analysis

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of natural signals. We find it remarkable that an ideal-observer analysis, with appropriate biological constraints and zero free parameters, predict many of the dominant neurophysiological features of speed processing.

Acknowledgement: NIH Training Trant 1T32EY021462-01A1

31.15, *9:15 am*

Human cortical areas for headcentric motion in depth A.V. van den Berg[1](a.vandenberg@donders.ru.nl), David Arnoldussen[1]; [1]Radboud University Nijmegen Medical Centre,Donders Centre for Neuroscience,Donders Institute for Brain, Cognition, and Behaviour,aDepartment of Cognitive Neuroscience, Section of Biophysics

Retinal disparity is a major source of information about the depth structure of an object or a scene around the fixation point. Veridical shape, egocentric distance, or their time derivatives indicating shape changes and motion in depth relative to the head, are not directly given by the retinal disparity field. Headcentric motion in depth is given by the changing target vergence, which depends on the changes of retinal disparity and eye vergence. Here we investigated with fMRI which cortical areas responded to changing retinal disparity or changing headcentric disparity. We used wide-field flow patterns to simulate forward motion through a cloud of dots. We decoupled the optic flow from the disparity information by projecting the motion of each point onto a virtual Vieth-Muller torus. This attributes to each point the same horizontal retinal disparity, while the motion of the point as seen from the cyclopic eye remains as if the point moved in 3D space. By motion in depth of the Vieth-Muller projection surface - independent of the fixation point- we decoupled retinocentric and headcentric (horizontal) disparity. Thus, we manipulated independently the contributions of retinal- and headcentric change in disparity and optic flow to the perceived motion in depth. In eight subjects, changing vergence and changing retinal disparity evoked strong acitvity in early visual areas. Optic flow sensitive areas pMST, pVIP, V3A, and V6+ showed strong responses to changes in retinal disparity, but only V3A and V6+ showed strong responses to headcentric changes in disparity. BOLD responses to the headcentric not the retinocentric changing disparity were consistent with the perceived speed of changing distance.

Acknowledgement: NWO-ALW 818.02.006 to AV van den Berg

31.16, *9:30 am*

Are basic feed-forward mechanisms masquerading as complex top-down effects in Middle Temporal (MT) neurons? John A. Perrone[1](jpnz@waikato.ac.nz), Richard J. Krauzlis[2]; [1]The University of Waikato, New Zealand, [2]Laboratory of Sensorimotor Research, NEI, NIH. Bethesda, MD, U.S.A.

Some primate motion-sensitive Middle Temporal (MT) neurons respond best to motion orthogonal to a contour's orientation (component types) whereas another class (pattern type) respond maximally to the overall motion of a pattern and somehow disregard the motion of individual contours moving in different directions and speeds. It is possible to construct a model of the pattern-type MT neurons using simple integration of the activity generated in speed- and direction-tuned subunits and such a model can account for a wide range of MT neuron properties (Perrone & Krauzlis, JOV, 2008). However two sets of findings appear to challenge this simple model. Some MT neurons have been shown to change from pattern to component behavior over brief time intervals (Pack & Born, Nature, 2001) and when the amount of 'transparency' in a plaid stimulus changes (Stoner & Albright, Nature, 1992). These results suggest the existence of complex top-down feedback mechanisms that are considered to be beyond the scope of simple integration models. We tested our MT model using the same stimuli used in these two studies (presented as 256 x 256 pixel x 8 frame movies) and we were able to replicate the pattern-to-component effects. We discovered that the two types of V1 neurons feeding into our pattern units have slightly different time delays; this initially favors the component response thus mimicking the Pack & Born temporal effects. We also discovered that the Stoner & Albright plaid stimuli contain a contrast asymmetry that depends on the plaid direction and the intensity of the intersections. The 'transparent' intersection condition has higher contrast in the component directions compared to the plaid direction causing the model MT pattern units to act as component units instead. This behavior replicates the Stoner & Albright pattern-to-component effect. Both of these examples demonstrate that feed-forward mechanisms can produce apparent top-down effects in MT neurons.

Acknowledgement: Supported by the Marsden Fund Council from Government funding, administered by the Royal Society of New Zealand.

Visual memory: Precision, capacity

Sunday, May 12, 8:15 - 9:45 am

Talk Session, Royal Ballroom 4-5

Moderator: Timothy Brady

31.21, *8:15 am*

Ensemble representations inflate estimates of working memory capacity Timothy Brady[1](tbrady@wjh.harvard.edu), George Alvarez[1]; [1]Department of Psychology, Harvard University

A central question for models of visual working memory is whether the number of objects remembered depends on object complexity. Early research found that observers could remember fewer complex objects than simple objects (Alvarez & Cavanagh, 2004). However, Awh et al. (2007) showed that despite worse performance at detecting subtle changes in complex objects, observers maintained the ability to detect large changes (e.g., changing a cube to a Chinese character). This was taken as evidence that observers could remember 3-4 complex objects, but that they had lower fidelity representations of these objects. Here we show that this method greatly overestimates capacity for complex objects because it does not account for ensemble representations. 100 observers participated in a change-detection task with displays of cubes and characters. They had to detect changes both within-category and across-category. We found that the dispersion of the items within a category (how close together the cubes were) was a major predictor of success on across-category changes but not within-category changes. This suggests that an ensemble representation was responsible for the estimates of 3-4 low fidelity cubes, rather than an individual item memory. Consistent with this conclusion, a second experiment with heterogeneous displays (mixed sets of cubes, Chinese characters, polygons, and Snodgrass objects) disrupted grouping and observers remembered fewer than 2 objects even with across-category changes ($M=1.79$, significantly lower than displays with grouping present, $p<0.001$). Thus, observers are capable of remembering individual information about only 1-2 complex objects. This is in direct contrast to claims of slot models that suggest observers always represent 3-4 objects and only fidelity is affected by object complexity. Our results show the necessity of understanding the representations observers form when estimating capacity: in particular, the importance of taking ensemble representations into account given their prevalence in working memory displays.

Acknowledgement: Supported by the National Science Foundation (CAREER Award BCS-0953730 awarded to GAA).

31.22, *8:30 am*

Moving beyond storage limitations: Exploring the dynamic manipulation of representations in VWM Hrag Pailian[1](hrag.pailian@gmail.com), Justin Halberda[1]; [1]Psychological and Brain Sciences, The Johns Hopkins University

Our internal representation of a complex visual scene relies on the dynamic processing of information in visual working memory (VWM). Though traditional methods have focused on storage limitations, here we move beyond these issues to explore cognitive abilities for dynamically manipulating information in VWM. Along the way, we discover independent limits for the storage and manipulation of visual items (Exp.1), spared memory for unmanipulated items (Exp.2), and preserved memory for the initial state of manipulated items (Exp.3). We developed a novel task in which participants were presented with a memory display consisting of colored circles, whose colors disappeared to leave behind circular placeholders. Pairs of placeholders swapped positions a varying number of times, after which participants judged the hidden color of a probed placeholder. This task is analogous to change-detection, along with a manipulation component. In Exp.1, we varied set size (2, 3, or 4 items) and number of swaps (0-4 swaps). We found a systematic impairment of memory when manipulating 3-4 items that increased with swaps. In contrast, performance with 2 items was unaffected by swaps (Fig.1). In Exp.2, we manipulated the number of times the to-be-probed item participated in swaps. Accuracy systematically decreased as the probed item participated in more swaps. In contrast, memory for unmanipulated items (0 participations) was better than memory for manipulated items – suggesting some protection for unmanipulated items (Fig.2). In Exp.3, we had participants retain the initial configuration during the manipulations, and we tested memory for both during the probe period. We found that memory for the initial configuration remained unaffected across all numbers of swaps (Fig.3). These results suggest two independent

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limits in VWM for storage and manipulation. In a dynamic world, the mind requires the ability to dynamically manipulate working memory representations – not merely the ability to passively store static representations.

Acknowledgement: NSERC

31.23, *8:45 am*

Visual short-term memory resource is not shared among features

Hongsup Shin[1](hshin@cns.bcm.edu), Ronald Van den Berg[1], Wei Ji Ma[1]; [1]Baylor College of Medicine, Department of Neuroscience

There is an ongoing debate on whether the basic units of visual short-term memory (VSTM) are objects or features. The traditional way of framing this debate is: if capacity is four and each item has two features, can observers remember four or only two items? The problem here is that discrete-capacity models of VSTM have been discredited. According to the modern view of VSTM, memory resource is continuous, as well as variable across items and trials. The more resource an item receives, the higher is its mnemonic precision. In this new view, the question of how resource is distributed over features remains unaddressed. To examine whether VSTM resource is shared among features in the context of the variable-precision model, we used a change localization paradigm. On each trial, human subjects (n=8) briefly viewed four ellipses with random orientations and colors. After a 1-second delay, a second display containing four ellipses appeared, exactly one of which had changed. In the one-feature conditions, the change occurred always in the same feature – either orientation or color, depending on the experimental session. In the two-feature condition, on every trial, the change occurred randomly in either feature. Observers reported the location of the change. We tested two optimal-observer models, which differed in their resource allocation. In the independent-resource model, mean mnemonic precision for a given feature was identical between the one-feature and two-feature conditions. In the shared-resource model, the mean precision for a given feature was a proportion of the mean precision in the corresponding one-feature condition. We found that the independent-resource model better explained subject behavior; the log likelihood difference was -75.1 ± 11.9 (mean±SEM). This suggests that the mnemonic precision of a feature is not affected by the number of features, and thus that VSTM resource is not shared among features.

31.24, *9:00 am*

Working memory requires focal attention, fragile VSTM does not.

Yair Pinto[1](yair.pinto@gmail.com), Ilja Sligte[1], Victor Lamme[1]; [1]Brain and Cognition, Department of Psychology, University of Amsterdam

Is visual memory dependent on attention? We tested this basic question in a partial-report change detection task that gauges three types of visual short-term memory (VSTM): iconic memory, fragile VSTM (fVSTM) and working memory. Participants had to judge whether a memory display containing eight oriented rectangles was identical to a test display that was presented after a blank interval or whether one of the rectangles had changed its orientation between successive views. In both the iconic memory and fVSTM condition, a retro-cue appeared during the blank, while in the working memory condition a post-cue appeared together with the test display. In all cases, the cue validly indicated the location where the potential change would happen or had happened. In the iconic memory condition, the cue appeared just after offset of the memory display. In the fVSTM condition and the working memory condition, the cue appeared 1 second after offset the memory display, yet respectively before or after presentation of the test display. Crucially, each trial was preceded by a predictive cue (pre-cue) with 75% validity. Thus, if subjects would selectively encode the single pre-cued item, they would perform correctly on the majority of trials. Indeed, when the pre-cue was valid, performance in all memory conditions was nearly perfect. However, upon invalid pre-cuing, performance in the working memory (post-cue) condition collapsed nearly to chance levels, while performance was only slightly impaired in the iconic memory and fVSTM condition. Altogether, these results suggest that focal attention is crucial for visual working memory storage, while it is less important for iconic memory and fVSTM. In line with previous behavioral (Vandenbroucke et al., 2011) and magnetic stimulation studies (Sligte et al., 2010), this study again implies that fVSTM is a memory storage that can be dissociated from visual working memory.

Acknowledgement: FP7 - Marie Curie IEF grant

31.25, *9:15 am*

A direct link between primary visual cortex functioning and iconic memory capacity

Ilja G. Sligte[1,2](i.g.sligte@uva.nl), H. Steven Scholte[1], Anouk M. van Loon[1], Victor A.F. Lamme[1]; [1]Brain & Cognition, Department of Psychology, University of Amsterdam, the Netherlands, [2]Visual Experience Lab, Department of Psychology, University of Birmingham, United Kingdom

While iconic memory has been studied for over 50 years, very little is know about its neural basis. In part, this is due to the difficulty of studying neural correlates of a memory storage that has brief lifetime (requiring fast neuroimaging techniques) and high capacity (requiring precise imaging methods). Here, we take a rather indirect approach to investigate the neural basis of iconic memory. In the first voxel-based morphometry (VBM) study, we investigated which neural structures correlated with iconic memory capacity and we observed that people with larger grey matter volume in the calcarine sulcus could report more information from iconic memory. In a second study employing magnetic resonance spectroscopy (MRS), we found that people with higher GLX concentration (glutamate/glutamine) in primary and secondary visual cortex seemed to have higher iconic memory capacity. As both these studies are correlational in nature, we aimed to confirm our findings in a causal way by manipulating GLX and GABA concentration in primary/secondary visual cortex. We did this by applying transcranial direct current stimulation (tDCS) over visual cortex with a reference electrode over motor cortex (see Stagg et al., 2009; anodal tDCS selectively lowers GABA, cathodal tDCS lowers GLX and GABA). Indeed, we observed significant modulations in iconic memory capacity after application of tDCS. Importantly, in all these studies no relation between visual working memory capacity and brain volume/neurotransmitter concentration in primary visual cortex was found. Altogether, these results show that there is a causal link between primary cortex functioning and iconic memory capacity.

Acknowledgement: Newton International Fellowship

31.26, *9:30 am*

Variability in color working memory precision reflects inherent stimulus properties

Gi-Yeul Bae[1](freebird71@gmail.com), Colin Wilson[1], Jonathan Flombaum[1]; [1]Johns Hopkins University

State of the art visual working memory models suggest that resources are not only continuous, but also variable across items and trials. The cause of trial-to-trial variability remains unknown, with several possibilities proposed (e.g., doubly stochastic neural representation). One important possibility is that variation is due to the particular stimulus values presented in a trial. To explore this possibility, Experiment 1 used delayed estimation for color, testing participants at a memory load of one, probing each of 180 colors ten times. We found clear differences among these colors in average recall precision. Experiment 2 replicated a study by van de Berg et al. (2012), and fit their variable-precision model to the results. We averaged the model's precision estimates for each color, and correlated these averages with the values obtained in Experiment 1. The correlation was highly significant, both overall and for each memory load, suggesting that differences among stimulus values account for a large proportion of the trial-to-trial variance. Experiment 3 investigated one reason why responses for certain colors might be more precise than for others. Participants were asked to identify the most prototypical example of each of seven colors by marking a color wheel. The least frequent selections served as good proxies for color category boundaries. We averaged the trial-to-trial variance estimates within each category for Experiment 1; these estimates correlated significantly with estimates derived in the same way for each color category at each memory load in Experiment 2. These results again suggest that trial variability is stimulus driven, perhaps reflecting categorical effects in color perception. This has important implications for modeling visual working memory, primarily, via the opportunity to account for trial variability with independent estimates of stimulus perception. We discuss a number of possible models employing such an approach.

Color and light: Appearance

Sunday, May 12, 10:45 - 12:30 pm

Talk Session, Royal Ballroom 1-3

Moderator: Roland Fleming

32.11, *10:45 am*

Do asymmetric color matches predict cross-illumination color selection?

Ana Radonjic[1](radonjic@sas.upenn.edu), Kira DiClemente[1], David Brainard[1]; [1]Department of Psychology, University of Pennsylvania

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See page 3 for Abstract Numbering System

In a typical color constancy study, the observer adjusts a test surface seen under some illuminant to match a target surface seen under a different illuminant. Do such asymmetric matches predict behavior in a more natural task in which the observer selects an object based on color? We measured constancy using two tasks. In our color selection task, observers viewed a target square against a variegated color background under simulated illuminant D65. The target was surrounded by four test squares under a test illuminant (4500°K or 12000°K): two squares were dissimilar distractors, and two were competitors whose degree of similarity to the target varied. We asked four observers to select the test square closest to the target in color (neutral instructions). For each of four targets, we derived a selection-based match using maximum likelihood difference scaling. We compared these to actual asymmetric matches obtained for the same stimulus configuration. The two types of matches were in good agreement. In both cases, the overall level of constancy was low. We repeated the experiment with three additional groups of observers, each given different instructions (judge the apparent reflectance of the stimuli, the physical reflectance of the stimuli, or the physical spectrum of the light reaching the eye). Performance for the physical spectrum instructions was similar to that for the neutral instructions. The apparent and physical reflectance groups were different. First, observers in these groups showed higher constancy. Second, the asymmetric matches no longer predicted observers' choices. Third, there was more individual variation within these groups. For our simple stimulus configuration, the relation between asymmetric matches and color-selection depends on instructions. The performance of observers in the reflectance groups suggests that they may employ a different processing strategy from the observers in the other two groups, possibly one involving explicit reasoning.

Acknowledgement: NIH RO1 EY10016 and University of Pennsylvania Research Foundation

32.12, *11:00 am*

Large shift in color appearance induced by motion in context

Sang Wook Hong[1](shong6@fau.edu), Min-Suk Kang[2]; [1]Department of Psychology, Florida Atlantic University, [2]Department of Psychology, Sungkyunkwan University

Hidden formatting deleted. Delete this text! none;mso-layout-grid-align:none;text-autospace:none">Color appearance is not solely determined by spectral light reflected from a surface or an object. Surrounding chromatic context modulates the perception of color. Here we present a novel and strong chromatic induction, in which color appearance of a dot, presented on a equiluminant equal-energy-spectrum (EES) 'white' background, is largely de-saturated by presenting a moving dot with physically identical chromaticity. The direction of shift in color appearance is consistent with the one observed after prolonged adaptation to chromatic contrast. However, this chromatic induction should be distinguished from the color shift by prolonged adaptation in that this appearance shift occurs instantaneously after some dots set in motion. Furthermore, this large shift in color did not occur either when moving dots were achromatic (black or white) or when the chromatic contrast of the moving dot was opposite to the chromatic contrast of the stationary dot. We conclude that this de-saturation of color appearance of the stationary dot result from the reduced chromatic contrast between the stationary and the background due to chromatic contrast normalization. We will discuss the role of the chromatic and luminance channels, and the ON and OFF chromatic channels.

32.13, *11:15 am*

Color shifts caused by perceived structure-from-motion

Sarah Elliott[1](slelliott@uchicago.edu), Steven Shevell[1,2]; [1]Institute for Mind and Biology, University of Chicago, [2]Department of Psychology and Ophthalmology & Visual Science, University of Chicago

When a figure is segmented from a chromatic background using stereoscopic depth, only weak shifts in color appearance are found (Shevell & Miller, 1996). When, however, a figure is segmented from ground by percepts of transparent layers, shifts in color appearance are large (Wollschlager & Anderson, 2009). Color appearance, therefore, may depend critically on the specific perceptual attributes that segment an object from its chromatic background. This study shows that changes in color appearance due to chromatic adaptation depend on a cortical neural representation at the level of three-dimensional object perception. Shifts in the color appearance of an equilateral-triangle test (0.125 deg in area) were measured using a red/green hue cancellation technique following adaptation to a larger reddish background [$L/(L+M) = 0.75$, $S/(L+M) = 0.2$]. The test was perceptually segmented from the background using structure-from-motion so the overall percept was a separate triangular test field on a distinct background. The background was sprinkled with small dots (same chromaticity but slightly higher luminance) that were (i) stationary, (ii) randomly located on each successive frame, or (iii) presented so they were perceived to move coherently over time to create the percept of a 3D sphere. An important feature of the experimental design was that retinal adaptation within 1 deg of the test field was constant in all conditions. When the dot motion created the percept of a 3D sphere, the color shift induced by the background was reduced for three observers, compared to the stationary-dots condition. Randomly relocating dots on each frame also caused some reduction in the influence of the background, but significantly less reduction than when the dots gave the percept of a 3D sphere. In sum, central neural mechanisms of object perception significantly alter the color-appearance changes caused by a given chromatic adapting light.

Acknowledgement: NEI EY-021036 (SE), NEI EY-04802 (SS)

32.14, *11:30 am*

Effects of short-term memory on perceived hue

Maria Olkkonen[1](maria.olkkonen@rutgers.edu), Sarah Allred[1]; [1]Rutgers – The State University of New Jersey

Background. For surface color to be useful for object identification, the surface color must be estimated from the incoming light signal and then compared to a memory representation of the object being identified. Color constancy and color memory have been extensively studied individually, but their relationship has rarely been addressed. Here we investigate the relationship between color constancy and color memory by separately and jointly measuring the effects of chromatic context and delay on hue matches. Methods. 8 observers compared the hue of two briefly presented 2-degree patches in a 2AFC experiment. Three reference patches (yellow-green, green, blue-green) were employed. Patches were presented: 1) with a 2 second inter-stimulus interval on a uniform surround (memory condition); 2) simultaneously with a hue difference between the reference and test surrounds (constancy condition); or 3) with both the delay and the surround difference (combined condition). We fit psychometric functions to the proportion-bluer data in each condition and estimated the bias (the point of subjective equality). The independence of color perception and memory was assessed by quantifying the degree of additivity in the combined matches. Results. The surround expectedly caused a hue bias in the constancy condition. More surprisingly, the delayed hue matches in the memory condition were also systematically biased. A control experiment with multiple stimulus ranges suggested that this was due to a central tendency bias. In the combined condition, the bias for all observers was around half that expected from linear addition of the memory and constancy biases, showing significant subadditivity of constancy and memory. A Bayesian model incorporating increasing noise during the delay and a prior set by the stimulus range accounted for both biases. Conclusion. The delay bias and the subadditivity suggest interactions between perceptual and short-term memory processes that can be parsimoniously accounted for within a Bayesian framework.

Acknowledgement: NSF CAREER BCS 0954749

32.15, *11:45 am*

Semantic effects on color afterimages

Gary Lupyan[1](lupyan@wisc.edu); [1]Department of Psychology, University of Wisconsin-Madison

To what degree is what we see influenced by what we know? In a series of simple behavioral studies utilizing a powerful color afterimage illusion, I show that knowledge of typical object colors strongly influences the colors people see. Participants were tested on a version of the 'Spanish Castle Illusion' in which adapting to a chroma-inverted image renders a subsequently presented grayscale image in vivid color until subjects moves their eyes (e.g., www.johnsadowski.com/big_spanish_castle.php). Participants adjusted the hue of the grayscale image displayed post-adaptation until it looked subjectively achromatic enabling accurate measurements of afterimage strength—e.g., a blue adaptor would induce a yellow afterimage requiring the addition of blue to offset it back to grayscale. Reliable afterimages were produced in all cases, but adapting to objects with intrinsic colors (e.g., a pumpkin) led to stronger afterimages than adapting to identically colored objects without intrinsic colors (e.g., an orange car). Semantic effects on perceived afterimages were greatly exagerrated when full-color scenes were used. Adapting to a castle scene containing intrinsically-colored components (grass, sky, etc.) produced afterimages that were 2.4 times stronger than those induced after adapting to a bookcase with arbitrarily colored books. These between-image differences disappeared if the adaptor induced an atypically colored scene or if upside-down images were used, as expected if decreases in familiarity reduce top-down predictive signals. The present results are consistent with recent findings showing that color afterimage signals originate from ganglion cell rebounds, which are then modulated at the cortical level just as other retinal inputs. This work goes beyond earlier demonstrations of effects of color memory on perception by showing that induced retinal activity is interpreted differently depending on the ecological likelihood of the resulting percept. In line with predictive-coding models of vision, retinal inputs that conflict with prior knowledge may lead to cortical discounting.

32.16, *12:00 pm*

When Color Flows With Shading: making depth disappear Daniel Holtmann-Rice[1](daniel.holtmann-rice@yale.edu), Emma Alexander[1], Roland Fleming[2], Steven Zucker[1]; [1]Department of Computer Science, Yale University, [2]Department of Psychology, University of Giessen

Our visual systems must decouple those shading variations due to geometric and lighting changes from surface material variations to infer surfaces. It is normally assumed that geometry and material changes are concurrently estimated, and others have implicated color/luminance interactions (the "color-shading effect"). In general, e.g. when viewing an apple, there are pigmentation changes and shading variations, but they develop by different physical processes. Hence they are, technically, independent. We show that when shading and color are made to flow dependently across an image, apparent depth disappears even for stimuli eliciting otherwise powerful shape percepts. Stimuli were rendered as a set of smooth, Lambertian surfaces, resulting in images with clear three-dimensional structure. By applying an equiluminant colormap to these images and then multiplying pointwise by the original intensity image, we obtain a final stimulus that contains the same luminance information as the original Lambertian renderings, but in which the orientation flows of color and intensity changes are identical. The shading percept in these stimuli is largely destroyed, but remains intact for images in which the colormap is applied to a grayscale image other than the original (e.g., another shape). We confirmed this effect psychophysically using a depth comparison task. Stimuli were constructed so that color flows were either: (i) dependent on the shading flows ("consistent"); (ii) independent of the shading ("inconsistent"); or (iii) the stimulus was simply the original rendering (control condition). Method: Two dots marked locations on each stimulus, and subjects reported which location appeared closer. Result: Subjects were significantly less accurate in the consistent condition than in either the inconsistent or control conditions, even without controlling for boundary foreshortening effects. Conclusion: When intensity variations are made to be geometrically consistent with hue variations, shape relief is impaired.

Acknowledgement: NSF, NIH, AFOSR

32.17, *12:15 pm*

Left middle frontal gyrus represents color categories but not metric differences in color; evidence from fMRI adaptation. Anna Franklin[1,2](anna.franklin@sussex.ac.uk), Samuel Berens[1], Chris M. Bird[1]; [1]The School of Pscyhology, University of Sussex, [2]The Sussex Colour Group, University of Sussex

The network of brain areas that support color vision has been known for some time. However, the areas of the brain that code color categorically have not yet been reliably identified. We used fMRI adaptation to identify neuronal populations that represent color categories irrespective of metric differences in color. FMRI adaption is a decrease in BOLD response due to repetitions of a stimulus that is represented by a population of neurons. Square stimuli were centrally presented on a calibrated MRI screen, and the color of the square changed pseudo-randomly 6 times between 2 colors within a 9.6 second block. The 2 colors were either from the same or different categories (e.g., 'blue 1 and blue 2' or 'blue 1 and green 1'), and the difference in CIE hue angle was varied so that there were small (26.37°) or medium (52.74°) or large (79.11°) chromatic differences. Participants were engaged in a target detection task that was unrelated to the color of the squares (task required detecting a luminance change in one of the squares; targets appeared in 12.5% of blocks). Despite the fact that color was irrelevant to the task, fMRI adaption for color category was present in the middle frontal gyrus in the left hemisphere. Specifically, BOLD response was reduced for repetitions of colors from the same category relative to colors from different categories. Importantly, fMRI adaptation in this region was not modulated by the size of the color difference. The results indicate that neurons in the left middle frontal gyrus represent color categorically regardless of metric color differences. These findings extend our understanding of how the brain processes color, and also have implications for understanding the metric and categorical coding of visual information more broadly.

Acknowledgement: This research was funded by the European Research Council (Franklin PI, Project CATEGORIES, ref 283605).

Attention: Spatial selection

Sunday, May 12, 10:45 - 12:30 pm

Talk Session, Royal Ballroom 4-5

Moderator: Ricardo Max

32.21, *10:45 am*

Attention improves visual performance in amblyopic macaque monkeys Lynne Kiorpes[1](lynne@cns.nyu.edu), Amelie Pham[1], Marisa Carrasco[1]; [1]Center for Neural Science and Department of Psychology, New York University

GOAL. Amblyopia–a loss of acuity in one eye following abnormal binocular experience during an early critical period–is a developmental disorder affecting ~3% of children. Recent research suggests that in addition to primary visual loss, amblyopes may also have deficient attention mechanisms. We investigated covert endogenous attention in juvenile and adult non-human primate amblyopes and visually normal controls. Methods. We tested the effects of spatial cueing on subjects' ability to discriminate the motion direction (rightward or leftward) of a target (a vertical grating patch) viewed monocularly at varying levels of contrast. The target appeared amidst an isoeccentric (3.5º) circular array of seven evenly spaced, differently oriented grating patches. All gratings drifted at the same speed but in different directions. Eye position was monitored by a remote eye tracker. We compared performance under valid cue (indicating the position of the upcoming target) and neutral cue (indicating all possible locations) conditions for each eye of each subject. Results. We fitted psychometric functions to performance data and evaluated contrast gain (threshold shift) and response gain (change in maximum accuracy). The results showed that (1) attention improved accuracy and decreased reaction times for all eyes tested; (2) the effect of the valid cue was greater for amblyopic than for non-amblyopic or control eyes, so that performance for the two eyes of amblyopes was similar under valid cue conditions; (3) for amblyopic eyes, attention improved performance consistent with a change in both response gain and contrast gain, whereas for non-amblyopic and control eyes only contrast gain was observed. Conclusion. The results indicate that covert endogenous attention can improve amblyopic vision. We will discuss the distinct pattern of attentional effects for amblyopic eyes and control eyes according to a normalization model of attention.

Acknowledgement: Supported by NIH R01s EY05864 to LK and EY016200 to MC

32.22, *11:00 am*

Cueing Attention Takes More Time in Strabismic Amblyopes Xin Jie Lai[1](angela@ski.org), Suzanne McKee[1], Chuan Hou[1], Preeti Verghese[1]; [1]The Smith-Kettlewell Eye Research Institute

Previous studies have shown that amblyopic observers, like normal observers, can use visual cues to enhance contrast detection of peripheral targets (Sharma et al, 2000; Kiorpes et al., 2012). However, attentional processes in amblyopes appear to differ from normal (Popple & Levi, 2008; Farzin & Norcia, 2011). We speculated that strabismic amblyopic observers might take longer to use cues, meaning that the asynchrony between cue and test target that produced enhanced contrast detection would be delayed relative to normal observers. To test this idea, we measured the timing of central and peripheral cues in normal and amblyopic observers. Observers were asked to judge the orientation (horizontal or vertical) of a threshold Gabor patch (2cpd, 60 msec duration) presented at 7 degrees eccentricity in one of four quadrants, chosen at random. The onset asynchrony between cue and test patch was varied randomly from trial to trial. The peripheral cue was a large square that framed the target location; the central cue was a short line presented near fixation that pointed to the quadrant where the target would appear. Observers viewed stimuli in a stereoscope, where targets were presented monocularly to only one eye, or binocularly at random to either the right or left eye. For both normal and amblyopic observers, the asynchrony that produced enhanced detection was shorter for peripheral than for central cues, consistent with previous findings (Nakayama & MacKeben 1989; Cheal & Lyon, 1991). However, for amblyopes, cue enhancement was delayed compared to normal for both types of cues. While there was no difference between monocular and binocular conditions for normal observers, the added burden of monitoring both eyes simultaneously in the binocular condition further delayed cueing in these stereo-blind strabismics. The ability to direct attention quickly to targets of interest is impaired in strabismic amblyopia.

Acknowledgement: The Smith-Kettlewell Eye Research Institute, Pacific Vision Foundation

 See page 3 for Abstract Numbering System

32.23, *11:15 am*

Exact Temporal Window of Visual Distraction Ricardo Max[1](ricardom@post.tau.ac.il), Yehoshua Tsal[1]; [1]Department of Psychology, Tel Aviv University

Distraction occurs when the perceptual system fails to avoid processing task-irrelevant stimuli (distractors) that are presented together with task-relevant ones (targets). The question whether distractors are processed before, concurrently with, or after targets are processed, bears crucial theoretical implications. Yet, direct behavioral investigations of the temporal loci during which distractors are processed remain largely absent in the literature. Theoretical models have instead adopted divergent assumptions regarding the time of distraction, which have led to disparate theoretical propositions about when and how attentional mechanisms operate. Early-selection and dual-process models assume that distraction occurs in the beginning of the presentation. Late-selection and single-process models assume that distractors are continuously processed for as long as presented. Perceptual load theory proposes that distractors are processed only after targets have been processed, when surplus resources remain available. We introduce the mutations paradigm, which allows for a direct assessment of the time window during which distractors are processed. Participants were presented with a central target flanked by two identical distractors. Distractors' identities could be either disruptive or neutral (non-disruptive). Distractors mutated once during each trial. There were three mutation types; disruptive distractors that mutated to neutral ones, vice-versa, or neutral distractors that mutated to different neutral distractors (control). In each trial, the mutation randomly occurred at one out of 11 times (between 17 ms and 187 ms after stimulus onset) (Fig. 1). Results revealed that (a) distraction occurred exclusively during the first ~50 ms following stimulus onset; (b) after ~50 ms, neither the presentation duration of distractors nor their identities affected performance (Fig. 2). That is, after ~50 ms all distracting stimuli were effectively disregarded. In accord with early-selection and dual-process theories of attention, we conclude that distraction occurs at extremely early stages, prior to the operation of attentional mechanisms that modulate processing.

32.24, *11:30 am*

Simultaneous cueing at two discrete locations and lag-0 sparing: breaking the attentional spotlight Brad Wyble[1](bwyble@gmail.com), Maxwell Bay[2]; [1]Department of Psychology, Pennsylvania State University, [2]Department of Neurology, UCLA

Visual attention is frequently described as a spotlight that can focus on one location to the exclusion of others, and there are hundreds of experiments that support variations of this theory. However, like Newtonian mechanics, a description of a system that is sufficient at one scale can break down at a finer scale, revealing a more fundamental mechanism. Here, we show that cueing benefits can be triggered simultaneously at two locations without affecting the intervening region of the visual field provided that the cues are simultaneous. Participants viewed 4 concurrent RSVP streams, searching for two simultaneous letter targets among digit distractors. Cues were red lines presented above and below a cued stream. The size of the cueing benefits from two simultaneous cues on both targets was large enough that we can discount a mixture model explanation in which attention is sometimes present at one location and sometimes at the other but never both (see supplement). These effects were similar regardless of whether or not the two targets were in the same hemifield. In further support of simultaneous attention to two locations, we found in a second experiment that two targets are perceived more often when presented simultaneously than when offset by 100-300ms. These results are well explained by a gain-field theory (Cheal, Lyon & Gottlob 1994) in which the state of attention can vary at each location across the visual field. In this model, attention does not reside at any one location but can be active at multiple locations simultaneously. Two simultaneous cues or targets can evoke attention at two locations. However, if one target is given a 100ms headstart over a second target, the attentional focus collapses around that first target, producing behavior consistent with a unitary spotlight of attention.

32.25, *11:45 am*

Does exogenous attention modulate endogenous attention? Michael A Grubb[1](michael.grubb@nyu.edu), Alex White[1], David J Heeger[1,2], Marisa Carrasco[1,2]; [1]Psychology, New York University, [2]Neural Science, New York University

Goal: Covert spatial attention modulates visual performance via endogenous (voluntary, sustained) and exogenous (involuntary, transient) mechanisms. Most studies have investigated one type of attention or the other, and little is known about how the two interact. Here we explored how exogenous cues affect the magnitude of endogenous attentional benefits. Methods: On each trial, spatial attention was manipulated, and two Gabor patches were simultaneously presented for 80ms (6.4° eccentricity to the left and right of fixation). A response cue appeared after their offset, indicating which was the target. Observers reported its orientation, clockwise or counterclockwise of vertical. Two endogenous and three exogenous cue conditions were crossed for a total of 6 conditions. The endogenous cues were valid or distributed. In valid trials, a white line appeared 400ms before the Gabors, pointing towards the location of the upcoming target (100% validity). In distributed trials, two white lines indicated that the target could appear at either location. The exogenous cues were valid, invalid or absent. In valid trials, a small white circle appeared for 60 ms, 100 ms prior to stimuli onset, just above the target location; in exogenous invalid trials, the circle appeared above the other stimulus; in exogenous absent trials, no circle appeared. Results: Both exogenous and endogenous attention improved performance. For each endogenous cue condition, accuracy in exogenous valid trials was significantly greater than in exogenous invalid trials. For each exogenous cue condition, accuracy in endogenous valid trials was significantly greater than in endogenous distributed trials. There was no interaction: the magnitudes of the endogenous benefits in each exogenous condition were statistically indistinguishable from each other. Conclusions: Exogenous attention improved performance but did not modulate the magnitude of endogenous attentional benefits. This suggests that these two types of attention draw on processing resources that are at least partially independent.

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32.26, *12:00 pm*

Simultaneous enhancement and suppression of distinct spatial locations Andrew Leber[1](leber.30@osu.edu), Rachael Gwinn[1], Ryan O'Toole[2]; [1]Department of Psychology, Ohio State University, [2]Department of Psychology, University of New Hampshire

Since von Helmholtz's early studies of covert attention, it has been known that individuals can flexibly and voluntarily enhance the processing of stimuli at cued spatial locations. More recently, researchers have also characterized a complementary capacity to suppress cued locations. What remains unknown is how these functions of enhancement and suppression interact and whether or not they work independently. Here, we specifically questioned whether the two functions could be implemented simultaneously. Observers searched displays in which one location contained a target while another contained a salient, irrelevant distractor. Prior to the display onset, long and short arrow cues were presented; the former predicted the target with 70% validity and the latter predicted the distractor with 70% validity. Results showed a moderate target-validity effect but no distractor-validity effect. Upon considering the high-level demands on observers to process multiple cues, our next experiment circumvented this roadblock using via incidental learning. Now only one arrow cue was presented, predicting the target with 70% validity; also, unbeknownst to observers, this same cue predicted the distractor with 70% validity. Results now showed a robust target validity effect, confirming that the cues were attended and used. Critically, a learning effect emerged over time, in which interference from the salient distractor became significantly reduced. These results demonstrate that with a carefully devised experimental procedure, individuals do indeed simultaneously enhance and suppress multiple noncontiguous locations in the visual field. However, further analysis revealed a striking caveat: simultaneous enhancement and suppression only occurred when the target and distractor were presented in opposite visual hemifields, presumably relating to the hemispheric independence of attentional resources (Alvarez & Cavanagh, 2005). We thus conclude that the functions of enhancement and suppression can be used flexibly; however, they compete for common resources and are thus not fully separable in nature.

Acknowledgement: NSF BCS-1027054 and US-Israel BSF 2009425 to A.B.L.

32.27, *12:15 pm*

Differential effects of transient attention on inferred parvocellular and magnocellular processing Yaffa Yeshurun[1](yeshurun@research.haifa.ac.il); [1]University of Haifa

Previous studies suggest that transient attention favors parvocellular over magnocellular processing. Three studies tested this hypothesis. The first study employed the pulsed-pedestal paradigm (a simultaneous brief presentation of target and pedestals) and the steady-pedestal paradigm (a brief presentation of the target against continuously presented pedestals), whose processing is thought to be mediated by the parvocellular and magnocellular pathways, respectively. Attention was triggered by peripheral precues added to these paradigms. As expected, transient attention improved performance with the pulsed-pedestal paradigm but not with the steady-pedestal paradigm. The second study explored the

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effects of transient attention on adaptation to spatial frequency and orientation because the parvocellular system processes high frequencies while the magnocellular system processes low frequencies. Two adaptation procedures were employed: one with separated adaptation and test phases and another with intermixed adaptation and test trials. High or low frequency Gabor patches were employed as targets. Peripheral or neutral cues preceded the adaptation displays. There was no attentional manipulation in the test trials. As expected, adaptation effects were increased by transient attention in the high-frequency condition but decreased in the low-frequency condition. The third study examined the effects of transient attention on motion aftereffect (MAE). It was previously demonstrated that adaptation to two superimposed gratings with different spatial frequencies leads to: a) MAE in opposite direction to that of the high frequency grating with a static test stimulus; and b) MAE in the opposite direction to that of the low frequency grating with a flickering test stimulus. Here, attention manipulation was added but only in the adaptation trials. The results reveal an attentional prolongation of MAE when measured with a static stimulus but MAE shortening when measured with a flickering stimulus. The outcome of these three studies can only be explained by an attentional mechanism that favors parvocellular over magnocellular processing.

Perception and action: Complex actions, clinical

Sunday, May 12, 8:30 am - 12:30 pm
Poster Session, Royal Ballroom 6-8

33.301 **When what we need influences what we see: A demonstration of embodied perception in the built environment** Guy Taylor-Covill[1](gat690@bham.ac.uk), Frank Eves[1]; [1]College of Life and Environmental Sciences, University of Birmingham

Recent reports question the evidence for an 'embodied' perception of geographical slant. While Proffitt (2006, 2011) and colleagues contend that slope perception is malleable to fit with an individuals' level of available energy resources, Durgin and colleagues (2010, 2011) argue much of the evidence for this model is an artifact of experimental design. New approaches to the study of slope perception are required to resolve this debate. Research has revealed that higher circulating blood glucose reduces the perceived overestimation of hill slope due to boosting available energy for climbing (Schnall et al, 2010), a finding that is also questioned (Durgin et al, 2012). Here, we report two studies that test the premise of Schnall and Proffitt's work in the field using a 'post-choice paradigm' which diminishes the possibility of demand characteristics influencing perceptual judgements. Participants (n=414) recruited in the built environment provided verbal, visual and haptic slope estimates of a large staircase (6.45m) either before (exp. 1) or after (exp. 2) choosing from a selection of fruit and drink items differing in energy content. Unbeknownst to participants, their choice of item represented their experimental grouping. In both studies, participants opting for items more likely to replenish their energy stores estimated the staircase as steeper, indicating perception was rescaled in line with energy needs. This result remained robust when controlling for influences of participant demographics, and ratings of perceived climbing effort, suggesting a process where implicit knowledge of available energy resources manifests in explicit perception of a locomotor challenge. The current findings confirm predictions of Schnall and Proffitt's model with a new, ecologically valid approach that minimizes potential effects of experimental demands.

33.302 **The presence of an out-group person reduces the range of near space** Zhenzhu Yue[1](yuezhenzhu@gmail.com); [1]Department of Psychology, Sun Yat-sen University

The space around us and within arms' reach is known as near (peripersonal) space, generally less than about 60 cm. It has been known that near space is represented differently as far (extrapersonal) space. For example, in a line bisection task, participants are required to bisect lines at different distances, showing a leftward bias in near space and a rightward bias in far space. In the present study, we investigated whether the presence of others affected the transition from near to far space. In Experiment 1, participants were required to bisect a line (10 cm or 40 cm) in near space alone or with another person of different gender who sat opposite to actual participants. A contraction of near space was observed, because participants showed a rightward bias to the real midpoint of the line at 40 cm in the two-people condition, but not in single-person condition. By contrast, a significant leftward bias to the real midpoint of the line at 10 cm was observed for both conditions. However, such an effect disappeared in Experiment 2 when the gender of two people was the same in the two-people condition. In Experiment 3, two people of same gender were controlled from either ingroup or outgroup, and they bisected a line (28 cm or 58 cm) together. A reduce of near space was observed for the outgroup condition, i. e. a rightward bias for the line at 58 cm, but not for the ingroup condition. By contrast, no such effects at was observed for the line at 28 cm in both conditions. Our results support that the presence of others does not necessarily influence the range of near space. However, a stranger from another categorization (e.g. different gender or group identification) could reduce the extent of near space.

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33.303 **Visual Guidance When Army Crawling Under Barriers** Shaziela Ishak[1](sishak@ramapo.edu), Adam Assoian[1], Joseph Lehan[1]; [1]Psychology, Ramapo College of New Jersey

Despite its everyday relevance, few studies have examined how our visual perception is affected when objects are attached to the body. Successfully fitting through openings with objects involves visual guidance of movement. For adaptive motor control, we must recognize prospectively that actions such as wearing a bulky coat, holding a computer, or moving furniture changes which openings we can fit through. Inaccurate decisions can lead to injury or property damage. We assessed adults' perception of affordances for army crawling (stomach touching the ground) in a person-plus-object system. Participants were presented with randomly ordered overhead barriers of different heights (10 to 70cm). Barriers were 15, 20, 25, 30, or 35cm larger than participant's sagittal body width. For each trial participants army crawled under a barrier then, choose a backpack (10, 15, 20, 25, or 30cm thick) to wear, and finally crawled back under the barrier wearing the backpack. Participants were asked to pick the largest backpack they thought they could wear to army crawl without touching barriers. Videos revealed that participants rarely looked at barriers as they crawled under them without backpacks. Nonetheless, participants found another source of visual information. Almost every participant looked back and forth between backpacks and barriers for every trial when choosing a backpack. Participants reported combining proprioceptive and visual information about backpack and barrier heights in their decisions. Most adults displayed conservative response criteria: picking backpacks a level smaller than the barrier. For the +25-cm barrier 50% choose the15-cm bag but for +30-cm barrier 50% choose the 20-cm bag. This pattern led 42% of participants to refuse backpacks for the smallest barriers. Participants did not always leave of safety margin, 83% of participants hit different barriers at least once. Findings are discussed in terms of combining visual and proprioceptive information to make adaptive decisions.

Acknowledgement: Ramapo College Foundation

33.304 **Effect of walking, running, and an end-task on object circumvention direction in soccer players and non-athletes** Erin Grand[1](gran4920@mylaurier.ca), Michael Cinelli[1], Pamela Bryden[1]; [1]Wilfrid Laurier University

Object avoidance strategies are dictated by the layout of the environment. Little research has examined obstacle avoidance at varying speeds and with the inclusion of an end-task. The purpose of this study was to examine the effects of sport-specific training, locomotion speed, and an end-task on single obstacle circumvention direction. Participants (varsity soccer players, n=10 and gender matched non-athletes, n=10) travelled along a 13m pathway towards a goal marked on the floor and avoided a single obstacle placed in one of three medio-lateral locations: middle, 20cm left of middle (left), and 20cm right of middle (right). Participants completed four trials per obstacle location during four conditions: 1) walking; 2) running; 3) walking with an end-task (walk+kick); and 4) running with an end-task (run+kick). During the end-task conditions, a soccer ball was placed on the goal and was kicked at the wall with the inside of either foot. Results revealed that soccer players and non-athletes both avoided the obstacle toward the side that afforded more space and circumvented to the right more frequently when the obstacle was in the middle location. During the walk+kick condition, non-athletes avoided the obstacle to the right more often than soccer players ($p<0.05$) while during the run+kick condition both groups avoided to the right more often, regardless of obstacle location. It appears soccer players' direction of circumvention was most affected by the inclusion of an end-task and speed increase. When soccer players moved at speeds different from training, environmental cues dictated the direction of avoidance rather than the end-task. When performing faster, more familiar speeds, soccer players used end-state body orientation for kicking to dictate the direction of avoidance. Conversely, non-athletes performed uniformly across the end-task conditions, indicating that neither changes in approach speed, nor an end-task, have an effect on avoidance direction for this cohort.

33.305 **Athletes have superior kinesthetic feedback during the control of visually-directed action** Eliza Polli[1](epolli1@swarthmore.edu), Stephanie Lechich[1], Allison Coleman[1], Morgan Williams[1], Frank Durgin[1]; [1]Department of Psychology, Swarthmore College

Perceptual feedback is fundamental to the control of skilled action, and perceptual feedback includes more than vision. Here we provide evidence that athletes have more precise proprioceptive feedback than non-athletes when throwing to a visual target. This was investigated by having 71 participants (34 were varsity athletes) make 100 blindfolded beanbag tosses to a visual target 4 m distant. Prior to each throw participants viewed the target and then pulled down the blindfold. After each throw, participants made judgments of their proprioceptively-perceived performance on that throw (two forced choice judgments: left vs. right and short vs. long) prior to lifting the blindfold to see the actual outcome. This late visual feedback was to reduce drift in the calibration of throwing. A payment reward scheme emphasized throwing accuracy, and gave additional points for report accuracy – but only when the throw was near the target to avoid intentional misthrowing. In a control experiment (N=18), participants simply threw the beanbag with full vision throughout. Throwing performance was reliably more precise (lower SD) with full visual feedback for both athletes and non-athletes. Throwing performance was also better for athletes than for non-athletes in both sighted and blindfolded conditions, though sighted non-athletes out-performed blindfolded athletes. Most importantly, proprioceptive/kinesthetic JNDs computed for both aim and distance were highly correlated with blindfolded performance in both athletes and in non-athletes. Athletes showed greater perceptual precision than non-athletes overall. This differential proprioceptive/kinesthetic sensitivity is sufficient to account for quantitative differences in skilled performance both when blindfolded and when full visual feedback was present. Rather than speaking of visuo-motor tuning, we may think of skilled throwing performance as involving coordination of kinesthetic feedback (observed discrepancies between intended/predicted and produced action) and visual feedback about the outcome of that action.

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33.306 **The effects of specific athletic training with an increase in velocity of locomotion during a collision avoidance task.**

Allison Zakoor[1](zako3347@mylaurier.ca), Michael Cinelli[1]; [1]Kinesiology & Physical Education, Wilfrid Laurier University, Waterloo, ON

Previous research using an aperture crossing task has shown that specific athletic training influenced actions only when performed in a similar context to that in which it was trained (i.e., increased walking speed) (Higuchi et al., 2011). The objective of the present study is to examine the action strategies of individuals with and without specific athletic training, combined with an increased rate of locomotion during a collision avoidance task. Participants included varsity athletes specifically trained (ST, N=4) at fitting through narrow openings (i.e. offensive positions in football) as well as non-specifically trained individuals (nST, N=3). Participants ran towards a goal placed at the end of a 10m pathway, with two vertically oriented obstacles placed 5m away from the goal on either side of the path's centre line. The obstacles created an aperture width that ranged between 0.6 and 1.8 (increments of 0.2) times each participant's shoulder width (SW). Kinematic data was collected using an NDI Optotrak motion tracking system to monitor heading direction and body segment rotation. We hypothesized that athletes specifically trained in a related task will have a smaller Critical Point (i.e., change in action) than the non-specifically trained individuals, when moving at an increased rate of locomotion. Preliminary results revealed that nST individuals were more cautious than the ST individuals (CP=1.6 versus 1.4 SW). Results also revealed that ST individuals passed through obstacles that were between 1.0 and 1.4 SW with postural adjustments (i.e. shoulder rotation or shrug) and only changed travel paths when the apertures were <1.0 SW. Conversely, nST individuals made infrequent postural adjustments and chose to change travel paths at apertures 1.6 SW and smaller. Similar to previous aperture crossing research, ST and nST individuals show differences in action when a task is performed at a similar rate to training.

33.307 **Visually-Guided Collective Behavior in Human Swarms**

Kevin W. Rio[1](kevin_rio@brown.edu), William H. Warren[1]; [1]Dept. of Cognitive, Linguistic, and Psychological Sciences Brown University

Human crowds, like bird flocks and fish schools, display remarkable patterns of collective locomotion. Do these global patterns emerge from local visually-guided interactions between neighbors? Here we address this question by quantifying the coordination in position and heading between neighbors in a crowd. We collected naturalistic data from small "swarms" of 20 participants who walked in an open 12x20 m area for 2 min trials. Participants were instructed to randomly veer left or right while staying together as a group, remaining within bounds. There was no designated leader and no signal to turn. Head positions were tracked at 60 Hz using a 16-camera infrared motion capture system (Qualisys Oqus 500). We computed the difference in heading between each pedestrian in the interior of the crowd and each of their N nearest neighbors. The mean heading difference was small (M = -1.5°, SD = 23.1°) across all pairs of pedestrians, but the SD increased linearly with N. This indicates a strong local coupling of alignment in heading. For each pedestrian, we also computed the bearing direction of each neighbor relative to the crowd's mean heading. Neighbors are more likely to be found along the axis of travel (in front, behind) than perpendicular to it (alongside). This bias is consistent with observations of surf scoters swimming on the water's surface (Lukeman et al., 2010), but orthogonal to observations of flying starlings (Cavagna et al., 2010). The results suggest that pedestrians interact locally to align their heading and walk behind their nearest neighbors. This analysis of the local coupling field can be combined with models of pedestrian interactions, such as following (Rio & Warren, PED 2012), side-by-side walking (Page & Warren, VSS 2013), and heading alignment (Bonneaud & Warren, PED 2012) to simulate human crowd dynamics (Warren, Kiefer, & Bonneaud, VSS 2013).

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33.308 **A behavioral dynamics approach to obstacle detection and avoidance by patients with tunnel vision**

Adam W. Kiefer[1](adam_kiefer@brown.edu), Russell L. Woods[2], William H. Warren[1]; [1]Department of Cognitive, Linguistic & Psychological Sciences, Brown University, [2]Schepens Eye Research Institute and Massachusetts Eye and Ear, Harvard Medical School

Mobility issues are the typical sequelae of "tunnel vision" (severe peripheral visual field loss), and manifest in the difficulty patients have detecting and avoiding obstacles during locomotion. We examined the behavior of seven patients with tunnel vision (6˚-27˚ visual fields) and six normally sighted individuals as they walked toward a visible goal in a virtual environment with or without an obstacle present. Each obstacle was a pole 1.8m tall and either stationary or moving across the path of the participant. Stationary obstacles appeared at a distance of 4 or 6m and an angle of 1˚ from the path to the goal. The moving obstacles crossed the participant's path at 4 or 6m while moving at a constant speed (50%, 70% or 90% of the participant's preferred walking speed). All obstacles appeared after participants walked 1m, and participants pressed a button when they detected an obstacle. Based on detection rates for short 1.2m obstacles (Kiefer et al., 2012), the patients were divided into two subgroups: (1) a low-detection group and (2) a high-detection group. We simulated individual locomotor trajectories using Fajen & Warren's (2003) steering dynamics model. RMSE between the model and human heading time series revealed no significant differences between the normally sighted (M = 0.28˚ +/- 0.01˚), low-detection (M = 0.36˚ +/- 0.04˚) and high-detection (M = 0.30˚ +/- 0.03˚) groups with stationary obstacles; simulations with moving obstacles are ongoing. There was a trend toward greater variability in RMSE for both patient groups compared to the normally sighted group. The results indicate that tunnel vision patients have different detection strategies (Kiefer et al.), but once an obstacle is detected their locomotor behavior is similar to normally sighted pedestrians. Patients appear to exhibit noisier trajectories, perhaps due to difficulty tracking the obstacle as they fixate and steer toward the goal.

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33.309 **The 50s cliff: Perceptuo-Motor Learning Rate Across the Lifespan**

Rachel Coats[1](r.o.a.coats@leeds.ac.uk), Andrew Wilson[2], Winona Snapp-Childs[3], Aaron Fath[3], Geoffrey Bingham[3]; [1]Centre for Sport and Exercise Sciences, University of Leeds, [2]Department of Psychology, Leeds Metropolitan University, [3]Department of Psychological and Brain Sciences, Indiana University

Introduction: Many perceptuo-motor tasks require coordinated rhythmic movements of different limbs. People can only produce two stable coordination patterns without training: 00 and 1800. Others (e.g. 900) usually have to be learned. Surprisingly, there are no major studies of such learning across the lifespan. In 2010, we presented data from 20, 70 and 80 year olds. Here we present data from all decades from 20 to 80. Method ~10 participants in each decade from 20s through 80s took part. Two vertically displaced white dots appeared in a display against a black background. The computer controlled the top dot and the participant the bottom one using a joystick. The target coordinative pattern was displayed before participants attempted to produce it. There were three assessment sessions (Baseline, Post-training, Retention) each containing 12 trials (4 x 00, 1800 and 900) and five training sessions (each 10 x 900). During training, feedback was provided by changing the dots from white to green when the movement was at 900± an error band that decreased as performance improved. Results: All groups improved with training and all retained it except 60 year olds. An exponential model was fit to learning curves using two methods to yield convergent measures of learning rates that were found to decrease with age with modest decline until a steep drop after 50. Statistical analyses confirmed this picture. Overall, learning rates dropped by half. Conclusions: Although adults over 60 learn, they do so at half the rate. Programs for recovery from stroke and other conditions should respect these reduced yet effective learning rates. Multiple factors are likely responsible for the learning deficit that comes with age, but motion perception is likely to be a key factor in this case, and the 50s is the crucial decade.

33.310 **Impact of Visual Mirror Therapy on Phantom Limb Pain Following Amputation: Visual Responsiveness in Somatomotor Cortex**
Annie Chan[1](chanannie@mail.nih.gov), Emily Bilger[1], Sarah Griffin[2], Viktoria Elkins[1], Sharon Weeks[2], Lindsay Hussey-Anderson[2], Katie Hughes[2], Brett Monson[2], Molly Shaffer[2], Mikias Wolde[2], Howard Gilmer[3], Paul Pasquina[2], Jack Tsao[2], Chris Baker[1]; [1]Laboratory of Brain and Cognition, National Institute of Mental Health , [2]Department of Neurology, Uniformed Services University of Health Sciences, [3]National Rehabilitation Hospital

The vast majority of amputees experience phantom limb pain (PLP) in their missing limb. Visual input from mirror therapy has been widely reported to reduce PLP – amputees place a mirror between their missing and intact limbs, and then simultaneously move both the intact and phantom limb while viewing the reflected image of the intact limb moving in the mirror. Investigations in human and non-human primates have suggested that deprivation of somatosensory input can lead to cortical reorganization in the somatosensory cortex, and it has been proposed that PLP may be a consequence of such reorganization. We investigated the impact of visual input on PLP and cortical reorganization in amputees undergoing four weeks of mirror therapy. Eight lower limb amputees and age-matched controls completed three fMRI scans at two weeks intervals. After the first scan session (baseline), amputees began 15 minute daily sessions of mirror therapy and recorded their daily pain experiences. During each scan session, we measured activation elicited by visual presentation of limbs corresponding to the intact and amputated limb. We also measured somatomotor activation for the intact and amputated limb as well as adjacent body regions. Consistent with prior reports, we found a reduction in PLP with mirror therapy. Further, we observed differences in visually elicited activations that were modulated over the course of the mirror therapy. Visual presentation of a foot corresponding to the amputated limb (but not hands or a foot corresponding to the intact limb) produced stronger activation of somatomotor cortex than in controls, and the strength of this activation diminished following therapy. These results suggest that removal of somatosensory input due to limb amputation unmasks visual responses in somatosensory regions, which may contribute to or be a marker for PLP, and that mirror therapy helps to reverse these changes.

33.311 **Using multiple ports to learn visuomotor transformations could reduce the risk of human error in laparoscopic surgery**
O.T Giles[1](o.t.giles@leeds.ac.uk), R. Sutherland[1], A.D. White[1, 2], J.P. Lodge[2], M. Mon-Williams[1], R.M. Wilkie[1]; [1]Institute of Psychological Sciences, University of Leeds, Leeds, United Kingdom, [2]Department of Hepatobiliary and Transplant Surgery, St James's University Hospital, Leeds, United Kingdom

Laparoscopic surgery is a complex visuomotor task that takes many years to master. Surgeons have to manipulate long laparoscopic tools inserted through access ports in the abdomen wall whilst viewing the tools and workspace on a remote visual display (via an endoscopic camera) (see Figure 1, sup material). This decoupling of motoric workspace and visual display creates distorted visuomotor mappings which varies with camera and port position: when the port position is changed, different limb movements and forces are required to elicit the same visual outcome (the tools are 1st order sliding levers). It has been shown that exposure to a variety of visuomotor distortions improves learning of novel visuomotor mappings (Braun et al., 2009), however, it is not clear whether this finding generalises to the laparoscopic surgical environment. To investigate this we trained two groups of surgically naive participants on an aiming task using a laparoscopic training box. Participants used a laparoscopic tool to trace along the surface of a digitising tablet to control a visual cursor on a vertical display. Participants made movements to sequentially appearing targets and were instructed to move as fast and accurately as possible. One group was trained to complete this task by using only a single port, while the other group trained with three different ports. Both groups were then tested using a novel port the same distance from all training ports. Our findings revealed that exposure to multiple ports significantly improved performance when using the novel port (see Figure 2, sup material). This suggests the CNS is able to use information about multiple visuomotor mappings arising from port positions in order to improve future performance. Consequently we propose that visuomotor variation should be built into surgical training systems in order to reduce the risk of human error during clinical practise.

33.312 **Visual field defects, eye-movements and driving**
Callum Mole[1](ps09c2m@leeds.ac.uk), Matthew Smith[1, 2, 5], Georgios Kountouriotis[1,3], Catharine Chisholm[4], Bipinchandra Bhakta[2], Richard Wilkie[1]; [1]Institute of Psychological Sciences, University of Leeds, UK., [2]Academica Department of Rehabilitation Medicine, University of Leeds and Leeds General Infirmary, UK, [3]Department of Psychological & Brain Sciences, Indiana University, [4]Division of Optometry, University of Bradford, UK, [5]Airedale Foundation NHS Trust, UK

Driving a car is for many in the aging population an essential part of maintaining mobility and quality of life. Older adults are more susceptible to stroke, which can cause visual field deficits that often preclude patients from driving based on pre-set visual field requirements (DVLA). However, despite these visual deficits some individuals may be able to adapt (e.g. by adopting compensatory eye-movement strategies such as increased scanning of the visual scene; Coeckelbergh, Brouwer, Cornelisson et al., 2002). To examine this further we used a simulated driving scenario where participants were asked to maintain one of 3 potential starting positions along a virtual roadway and measured eye movements and steering performance. We tested 15 stroke patients with either left or right homonymous hemianopia (LHH/RHH) or left visual inattention (LVI) and 16 healthy age-matched controls. Our findings showed that the nature of visual impairment differentially affected steering behaviour. VI led to marked steering deficits across all road positions compared to controls, LHH only displayed deficits when trying to maintain a leftward starting position (and RHH performed similar to controls). When examining individual performance some patients appeared to demonstrate normal steering performance despite visual deficits. Distinct gaze pattern differences may help explain these individual differences since successful steering was associated with directing eye-movements towards the regions on the road they were required to steer through (rather than being locked in a fixed direction). We suggest that our experiment indicates that compensatory eye-movement strategies may have the potential to moderate steering deficits related to visual impairment, providing an exciting avenue for directing future rehabilitative research efforts in driving after stroke.

Acknowledgement: Remedi

33.313 **Can an iPad task determine visuomotor deficits in children with ASD?**
Carmen, S. Baker[1](bake7070@mylaurier.ca), Pamela, J. Bryden[1], Michael, E. Cinelli[1]; [1]Kinesiology and Physical Education, Wilfrid Laurier University

Autism Spectrum Disorders (ASD) are clinically defined through subjective measures. However, there is conclusive evidence of quantifiable motor deficits characterized in ASD. The objective of this study was to determine if a visuomotor memory task could be used to quantify differences between typically developing children and those with ASD. Children clinically diagnosed with ASD and no other comorbid intellectual disabilities (N=9) between the ages of 6 and 13 and typically developing children (N=17) between the ages of 5 and 8 participated in this study. All children performed a visuomotor memory task that was administered through a custom-made iPad application. The task began when the participants placed their index finger on the "home" position at the bottom of the screen. Following a random fore period, a single target appeared at a random location on the black screen. The participants were asked to tap the target (a 1cm diameter yellow dot) as quickly and accurately as possible, however the target would disappear as soon as the participant lifted his or her finger off the "home" position. An independent samples t-test was conducted to compare tapping accuracy in both populations as measured by distance (in pixels) from the center of the target. Although not significant, children with ASD were less accurate (M=160.55, SD=168.17) than typically developing children (M=39.27, SD=18.27); t(11.4)=-2.03, p0.081. A Pearson correlation revealed that there was a negative correlation between the attention to detail component of the Autism Quotient questionnaire (AQ) and accuracy score in children with ASD (r= -0.7, n=8, p=0.026). These findings provide encouragement that a visuomotor memory task on an iPad can be used to detect motor planning deficits in children with ASD as well as provide an objective measure of severity within one component of the AQ.

Acknowledgement: Wilfrid Laurier University

33.314 **Exercise increases visual cognition in older adults**
Rebecca Reed-Jones[1,2](rjreedjones@utep.edu), Sandor Dorgo[1], Ashley Bangert[3]; [1]Department of Kinesiology, College of Health Sciences, The University of Texas at El Paso, [2]Physical Therapy Program, Department of Rehabilitation, College of Health Sciences, The University of Texas at El Paso, [3]Department of Psychology, College of Liberal Arts, The University of Texas at El Paso

Impaired vision is a significant independent risk factor for falls among older adults. Impaired vision is also associated with reduced spatial cognition in frequent fallers. Despite the evidence of a strong influence of visual cognitive factors on fall risk in older adults, most guidelines for fall prevention still only focus on visual acuity and corrective eyewear. Regular physical activity alleviates some of the issues related to falls risk (e.g. increased muscle strength, improved neuromuscular control, and reduced reaction time). Increased physical activity may also increase blood flow in the hippocampus, suggesting physical activity can improve spatial cognition. However, it is currently unknown how visual cognition changes with regular exercise participation. The purpose of the current study was to examine changes in visual cognition following a 12-week exercise intervention program. Thirty-four independent living older adults age 60 years or above participated in the study. Participants were involved in a 12-week program focusing on cardio-, strength- and balance-training of two sessions per week, 90 minutes per session. Tests of visual cognition included the Useful Field of View (UFOV) test, Simon task, and the number of obstacle collisions on an obstacle course. All tests were given Pre (prior to the intervention) and Post (at week 12) of the program. Results indicated that following 12-weeks of physical activity all measures of visual cognition improved. Divided attention of the UFOV significantly improved Pre to Post testing ($p < 0.05$). Also, significant increases in accuracy and decreases in reaction time on the Simon task were observed ($p < 0.05$). Finally, older adults significantly reduced the number of collisions with obstacles from Pre to Post testing ($p < 0.001$). These results suggest that regular physical activity benefits visual cognition in older adults, especially in the domain of spatial processing.

Acknowledgement: None

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33.315 **Training of compliance control in children yields improvements in handwriting** Winona Snapp-Childs[1](wsnappch@indiana.edu), Ian Flatters[2,3], Aaron Fath[1], Mark Mon-Williams[3], Geoffrey Bingham[1]; [1]Department of Psychological & Brain Sciences, Indiana University, [2]Department of Mechanical Engineering, University of Leeds, [3]Institute of Psychological Sciences, University of Leeds

Introduction: Children with Developmental Coordination Disorder (DCD) must overcome a 'catch-22' to achieve sensori-motor learning. They cannot produce movements well enough to improve. Snapp-Childs, Mon-Williams and Bingham (2012) developed a method that supports active movement generation to allow practice with improvement of good compliance control. They showed that the method allowed children with DCD to improve at a 3D tracing task to become as proficient as typically developing children who had also trained. In the present study, we examined the effect of this training on handwriting, specifically figure copying, in 7-8 year olds. Methods: Twenty-three children were tested with the Beery VMI (including tests of Visual Perception (VP) and Motor Coordination (MC)), the 3D tracing task, and a 2D letter-like figure copying task. The children then trained on the 3D tracing task until they all reached comparably good proficiency. The 3D tracing and copying tasks were tested again following training. Results: Performance on the Beery varied widely. Age referenced percentile scores ranged from 4-92 for VMI, 2-96 for VP, 0.7-73 for MC. Performance on the 3D tracing task at baseline varied as a function of the level of difficulty. After training, these differences were dramatically reduced. Baseline performance in both the 3D tracing and 2D copying tasks co-varied with VP scores (not VMI or MC scores) indicating that the ability to visually discriminate pattern detail predicts complex 3D path tracing and 2D line form copying. Again, following training, these relationships disappeared. For figure copying, the extent to which copied forms were larger than the target related inversely to error scores. Conclusions: Figure copying improved as a result of training on the 3D tracing task, reducing differences in size and error that co-varied with VP scores. In conclusion, the training method improved handwriting and reduced differences indicated by Beery scores

Acknowledgement: NICHD

Object recognition: Neural mechanisms

Sunday, May 12, 8:30 am - 12:30 pm

Poster Session, Royal Ballroom 6-8

33.316 **Action-specific predictive coding of object states** Nicholas C. Hindy[1,2](nhindy@princeton.edu), Nicholas B. Turk-Browne[1,2]; [1]Department of Psychology, Princeton University, [2]Princeton Neuroscience Institute, Princeton University

Our actions can determine visual input by changing the state of objects in the environment. Because the future state of an object is often predictable based on its current state and a planned action, such actions provide a rich source of perceptual expectation. We used fMRI and a novel training paradigm to test whether associative learning can induce predictive coding in visual cortex of what an object will look like after an action. Action-outcome training consisted of an exploratory phase and a directed phase. Each trial of the exploratory training phase began with a stimulus cue (fractal pattern) in the middle of a computer screen, and the subject chose to press the left or right button in order to replace the cue with an outcome fractal. For each cue, a particular outcome appeared when the left button was pressed and a different outcome appeared when the right button was pressed. The directed training phase was used to balance the frequency of specific cue-outcome transitions, with arrows appearing below fractal cues to prompt left and right responses. After both training phases, we used fMRI to assess the neural correlates and consequences of predictive coding for outcomes based on actions in the scanner. As during directed training, each trial in the scanner included three parts: a cue fractal, an arrow prompt to quickly press the corresponding left or right button, and then an outcome fractal. We compared trials in which the outcome was predictable given the cue and action combination, to trials in which the outcome was associated with the cue but only expected after the other action, and found that the BOLD response in object-selective visual cortex was affected by learned action contingencies. Actions and intentions may thus adaptively influence visual perception of objects via predictive coding of forthcoming object states.

Acknowledgement: NIH R01 EY021755 (NTB)

33.317 **Development of size- and view-invariance in LOC: an fMR-adaptation study** Mayu Nishimura[1](mayunishimura@gmail.com), K. Suzanne Scherf[1,2], Valentinos Zachariou[1,3], Michael J. Tarr[1], Marlene Behrmann[1]; [1]Department of Psychology, Carnegie Mellon University, [2]Department of Psychology, The Pennsylvania State University , [3]Laboratory of Brain and Cognition, NIMH/NIH

Previous studies have shown that by age 5-8 years, the lateral occipital complex (LOC) shows adult-like responses when contrasting images of objects versus scrambled objects. Here, we selected complex novel shapes and manipulated both size and viewpoint of these shapes in an adaptation paradigm to assess the neural profile in LOC in children (5-10 years), adolescents (11-16 years), and adults (18-27 years). Observers were shown blocks in which the same object was shown repeatedly, the same object was shown in different sizes/views, or different objects were shown. Hidden formatting deleted. Delete this text! yes"> The results showed that all 3 age groups demonstrated size-invariance, showing a reduced neural response to the same-object-same-size condition and the same-object-different-sizes conditions. However, only adults showed evidence of view-invariance. Adolescents and children showed a similar neural response to the same object different views condition and the different objects condition.Hidden formatting deleted. Delete this text! yes"> The results suggest that size-invariance develops early but the neural mechanisms underlying view-invariant object recognition is not yet mature even in adolescents.

33.318 **Neural mechanisms of dynamic object encoding** 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

Dynamic objects are effortlessly recognized across motion, viewpoint, and articulation. We investigated the perception and neural representation of dynamic objects using fMRI with both GLM and multi-voxel pattern analysis (MVPA). First, we identified brain regions recruited during dynamic object perception using a novel localizer which contrasted moving objects with phase-scrambled versions of the same moving objects. Static objects and scrambled objects were also included as comparisons to traditional LOC localizers. Results identified regions of occipito-temporal cortex largely overlapping with regions selective for static objects, but subsuming a larger area extending more dorsally to include the hMT+ complex and parietal regions. Second, we conducted several experiments to investigate the coding of dynamic objects over motion and articulation. Subjects viewed multiple example animations of novel articulating objects, which varied across viewpoint, size, and motion path. One experiment included three objects with eighty example animations for each; a second experiment included six objects with forty examples for each. A SVM pattern classifier was trained on one set of example animations, and tested on a different set of examples – examining whether a tested brain region encodes dynamic objects across motion, articulation and viewpoint. Classification was performed in ROIs identified with the dynamic object localizer and a motion localizer that identified hMT+. Results showed above chance classification in all ROIs, and chance classification in a control ROI in frontal cortex. A second assumption-free analysis employed a whole-brain searchlight classifier to search for areas that might encode information about dynamic objects. This searchlight identified additional regions that overlapped with parts of early visual cortex (determined by retinotopy scans), dynamic LOC, and hMT+. Our

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results indicate: that multiple areas of early and higher-level visual cortex are recruited during dynamic object perception and many of these areas encode information that is invariant across motion and state of articulation.

Acknowledgement: Funding provided by the Temporal Dynamics of Learning Center at UCSD (NSF Science of Learning Center SBE-0542013) and by an NIH EUREKA Award (#1R01MH084195-01) to MJT.

33.319 **What you find depends on how you look: Category selectivity in frontal cortex revealed by whole-brain correlation analysis**

Yida Wang[1](yidawang@cs.princeton.edu), Kai Li[1], Moses Charikar[1], Jonathan D. Cohen[2,3], Nicholas B. Turk-Browne[2,3]; [1]Department of Computer Science, Princeton University, [2]Department of Psychology, Princeton University, [3]Princeton Neuroscience Institute, Princeton University

Neuroimaging studies typically seek to associate evoked neural activity with specific cognitive processes. While successful, this approach might fail to reveal cognitively meaningful interactions between brain regions. Consider a region that is always engaged during object perception, but whose interactions with other regions depend upon the category of object being perceived. This region might only be identified as category selective based on its pattern of correlations with other brain regions. However, typical approaches for assessing correlations in neuroimaging data could also fail to identify this region, since they require selecting seed regions based on activity differences. Here we take a fresh look at category selectivity by surmounting these limitations, applying multivariate analyses to patterns of correlations rather than activity, and extracting correlations in an unbiased manner over the whole brain rather than among seeds. Subjects viewed blocks of faces or scenes. For each block, we computed the pattern of correlations over time of every voxel with every other voxel. We used a linear classifier to label patterns of correlations as having been obtained during face vs. scene blocks. To measure accuracy, we iteratively trained the classifier on one group of subjects and tested it on a new subject. Correlation patterns were highly discriminative of object category (91%, $p<4.2e-11$). To identify which correlations were category-selective, we examined the frequency with which each voxel was chosen during correlation-based feature selection. Beyond expected voxels in ventral temporal cortex, a large voxel cluster was obtained in medial prefrontal cortex. Applying the same kind of classifier to patterns of activity produced high classification accuracy, but did not include frontal cortex. These findings illustrate the power of exhaustive analyses of brain interactions, and suggest a broader research program to examine how patterns of correlations, and not just activity, may advance our understanding of human brain function.

Acknowledgement: Supported by the J. Insley Blair Pyne Fund (Princeton University) and the John Templeton Foundation.

33.320 **Large-scale functional distinctions in object cortex are reflected in resting state networks**

Talia Konkle[1,2](tkonkle@gmail.com), Alfonso Caramazza[1,2]; [1]Department of Psychology, Harvard University, [2]Center for Mind/Brain Science, University of Trento

Within the occipito-temporal cortex, object responses have a large-scale alternating organization related to two core dimensions of objects: animacy and real-world object size. To what extent is this large-scale functional organization of object responses related to differences in whole-brain network architecture? Participants underwent functional neuroimaging in which brain responses were recorded during (1) stimulus presentations of big and small animal and object images, and (2) resting state. We found large cortical zones with response preferences for either big objects, animals, or small objects, arranged in a spoked organization around the occipital pole, duplicated on the ventral and lateral surface of occipito-temporal cortex. Critically, regions with similar functional preferences were also more correlated with each other at rest than with the spatially proximate regions ($t(11)=2.2$, $p<0.05$), and this was also reflected in the correlation of the whole-brain networks ($t(11)=2.7$, $p<0.05$). Specifically, the two animate regions on the ventral and lateral surfaces (Fusiform, LO) were more correlated with each other than with adjacent big-object zones along ventral and lateral surface (PHC-parahippocampal, TOS-transverse occipital sulcus), and the same relationship held for the the big object regions. The small object zone (inferior temporal gyrus), was more correlated with the big object zones than the with adjacent animate regions, preserving the inanimate distinction. Thus, the large-scale organization of object response preferences across occipito-temporal is also evident in the structure of the neural correlations during rest. To the extent that resting state correlations reflect direct and indirect long-range connectivity, these results raise the intriguing possibility that the large-scale functional organization of object responses is in part caused by differences in whole-brain network architecture.

33.321 **Electrocorticography of category-selectivity in human ventral temporal cortex: spatial organization, responses to single images, and coupling with fMRI**

Corentin Jacques[1,2,4](corentin.g.jacques@uclouvain.be), Nathan Witthoft[1,2], Kevin S. Weiner[1,2], Brett L. Foster[1,3], Kai J. Miller[1,3], Dora Hermes[3], Josef Parvizi[1,3], Kalanit Grill-Spector[1,2]; [1]SHICEP, Stanford Human Intracrianal Cognitive Electrophysiology Program, [2]Department of Psychology, Stanford University, [3]Department of Neurology and Neurological Sciences, Stanford University, [4]IPSY, Research Institute for Psychological Science, Université Catholique de Louvain, Belgium

Both functional neuroimaging (fMRI) and electrocorticography (ECoG) research has revealed selective responses to faces, bodyparts, words and places, in human ventral temporal cortex (VTC). However, the precise spatial organization of ECoG selective responses in VTC, as well as the nature of the coupling between functional responses measured with ECoG and fMRI is poorly understood. To address these questions we measured category selectivity to faces, bodyparts, cars, and houses using ECoG and fMRI in six epileptic patients and precisely located ECoG and fMRI responses relative to each subject's cortical surface. Our data indicate a clear spatial organization of ECoG selectivity, where the mid-fusiform sulcus forms an anatomical boundary between regions showing preference to animate vs. inanimate categories. Specifically, ECoG broadband (30-160Hz) responses on the lateral fusiform gyrus and inferotemporal gyrus showed strong selectivity to faces, but responses in the mid fusiform gyrus, collateral suclus and parahippocampal gyrus showed a preference to houses and cars. Strikingly, an independent data set revealed that these preferential responses are reliable and are evident for individual images from these categories. We next compared the distributed pattern of ECoG selectivity with that measured with fMRI, finding significant correlations between the two measurements when the fMRI signal was extracted in the vicinity (3-5mm) of each electrode. The strength of this coupling varied with time and frequency band: early (100-350ms) ECoG responses across all frequency bands were positively coupled with fMRI, while later (>350ms) ECoG responses showed positive correlation with fMRI in the broadband range and negative correlation in low frequencies (4-12Hz). Our data thus reveal a clear spatial organization of ECoG category selectivity in VTC, which is evident even in responses to single images. Finally, the coupling between ECoG and fMRI selectivity in the human VTC depends on the timing and properties of neural response at different frequencies.

33.322 **Is the representation of target objects independent of their surrounding?**

Galit Yovel[1,2](galit@freud.tau.ac.il), Yaara Erez[1]; [1]School of Psychological Sciences, Tel Aviv University, [2]Sagol School of Neuroscience, Tel Aviv University

Target objects required for goal-directed behavior are typically embedded within multiple irrelevant objects. Recent neuroimaging studies reported mixed results on the extent to which distributed responses to objects in the lateral occipital complex (LOC) are independent of their task-irrelevant surroundings. To examine the effect of task-irrelevant clutter on the responses to objects we used functional magnetic resonance imaging (fMRI) and manipulated the type of clutter while subjects identified target objects. Target objects were presented either in isolation, in the presence of a homogeneous clutter, or in the presence of a heterogeneous clutter. We found that a heterogeneous but not homogeneous clutter interfered with decoding of target objects in the object area. Moreover, the response pattern to an isolated target object was more similar to its pattern when presented with a homogeneous clutter than when presented with a heterogeneous clutter. Interestingly, representations of preferred target objects in category-selective areas were not affected by the presence of the clutter or the type of the clutter. These findings suggest that attended preferred objects may be better secluded from irrelevant non-preferred objects within their category selective cortex. Our findings clearly show that the representation of target objects is not independent of their surrounding in LOC and that irrelevant clutter information is also represented. These findings further suggest that the variation among the non-target objects, rather than the number of non-target objects per-se, modulates the representation of target objects in LOC.

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33.323 **Learning to recognize degraded objects is associated with a greater match to the objects' template fMRI activation patterns in Lateral Occipital Cortex**

Zvi Roth[1,2](zvi.roth@mail.huji.ac.il), Ehud Zohary[1,2,3]; [1]Edmond and Lily Safra Center for Brain Sciences, Hebrew University of Jerusalem, [2]Interdisciplinary Center for Neural Computation, Hebrew University of Jerusalem, [3]Department of Neurobiology, Hebrew University of Jerusalem

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One feature of visual processing in the ventral stream is that cortical responses gradually depart from the physical aspects of the visual stimulus and become correlated with perceptual experience. Thus, unlike early retinotopic areas, the responses in object-related lateral occipital complex (LOC) are typically immune to parameter changes (e.g. contrast, viewpoint, etc.) when these do not affect recognition. Here, we use a complementary approach to highlight changes in brain activity that result solely from a perceptual state shift. We focus on LOC and early visual cortex (EVC) and compare their fMRI responses to degraded object images, prior to, and following perceptual learning that renders initially unrecognized objects, identifiable. Using three complementary analyses, we find that in LOC, learned recognition is associated with a change in the multi-voxel response pattern to degraded object images, such that the response becomes significantly more correlated with the pattern evoked by the intact version of the same image. This provides further evidence that the coding in LOC reflects the Gestalt, perceptual level of representation of visual objects

Acknowledgement: Supported by The HU-EPFL Collaboration Program

33.324 **Object sensitivity in subcortical nuclei and their functional connections with cortical areas** 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

Behaviors from blindsight patients as well as studies using interocular suppression suggest that the human subcortical pathway might be capable of processing object category information. Using functional MRI, we investigated subcortical response properties as well as functional connectivity patterns during object perception. During the experiment, subjects viewed objects from four different categories (tools, faces, phase-scrambled tools, phase-scrambled faces). Luminance and RMS contrast were matched for different stimuli. fMRI activity in the SC and LGN showed stronger responses to intact objects than to scrambled objects. We also performed granger causality analyses to investigate the functional connectivity of these subcortical regions with cortical regions underlying visual object processing. Preliminary results suggested a number of interesting connection patterns for different subcortical nuclei. For example, the left and right SC might have different connection patterns during object perception: although left SC showed more robust object sensitivity in terms of response amplitude, its signal was not related to responses in cortical areas; whereas right SC showed more correlation with responses in cortical areas, including both the parietal and fusiform areas. Thus we found object sensitivity in some subcortical structures, such as the SC and LGN. Preliminary results showed that subcortical nuclei might have differential patterns of communication with cortical regions during object information processing.

Acknowledgement: This research was supported by National Natural Science Foundation of China (No. 81123002)

33.325 **Bringing the real world into the fMRI scanner: Real objects amplify the neural correlates of valuation compared to photos** Jody C. Culham[1](jody.culham@gmail.com), Jacqueline C. Snow[1], Antonio Rangel[2]; [1]Brain and Mind Institute, Dept. of Psychology, University of Western Ontario, [2]Division of the Humanities and Social Sciences, California Institute of Technology

Our understanding of the cognitive and neural basis of object perception is largely based upon studies that have examined responses to drawings or photos of objects rather than actual objects themselves. Recent fMRI evidence from our laboratory (Snow et al., 2011, Scientific Reports) suggested that the neural mechanisms involved in processing or representing real objects differ from those of photos. Our fMRI results are supported by recent behavioral data on the influence of real objects on consumer behaviour. Bushong et al., (2010, American Economic Review) found that the form in which objects were displayed had a sizeable influence on participants value ratings. Specifically, students were willing to pay over 60% more for common snack foods when they were presented as real items versus color photos. Such goal-directed decisions can be identified in the form of a 'value signal' encoded in the ventro-medial prefrontal cortex (vmPFC) (Hare et al., 2009, Science). Here we used fMRI to monitor brain activity during trials in which hungry observers made behavioral decisions about their desire to consume common snack foods. Critically, we contrasted neural responses for real items vs. color photos of those items matched for features like size and viewpoint. We found that fMRI responses in vmPFC correlated significantly with observers' trial-by-trial value judgments about the foods, consistent with the earlier results. Strikingly, however, we found that the use of real items amplified value-based fMRI responses in vmPFC. Real items elicited FMRI responses in vmPFC that were more negative for aversive foods, and more positive for desirable foods, than those elicited by the corresponding photos. Our results reveal a neural correlate in vmPFC for the value-based differences associated with real-world objects over photos. Moreover, they provide further evidence that images are an imperfect proxy for real objects.

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33.326 **Suppression of visual stimuli with occipital and parietal TMS** Evelina Tapia[1](evelina@illinois.edu), Dustin J Martin[1], Diane M Beck[1]; [1]University of Illinois Urbana-Champaign

When transcranial magnetic stimulation (TMS) is applied over occipital cortex approximately 80-100 ms after the onset of a stimulus its visibility is decreased. The location of the occipital stimulation is typically selected by first determining where on the scalp TMS results in an experience of a phosphene. Recently it has been shown that phosphene sensations can also be elicited with parietal TMS (Marzi, Mancini, & Savazzi 2009). Our current study investigated whether TMS to parietal regions that elicit sensations of phosphenes also produce visual suppression, akin to that produced by occipital TMS, and if so, how the effects of suppression compare across the two areas. Occipital and parietal stimulation sites within the same hemisphere were selected according to whether they elicited phosphenes. Then, TMS was randomly applied at 0 to 130 ms after the onset of the stimulus (SOA) in steps of 10 ms to these areas. Participants responded to the orientation of the line stimulus and rated its visibility on every trial. Our occipital TMS data replicate previous reports of visual suppression around the classical 80-100 ms window both in the objective line orientation responses and subjective visibility ratings. TMS to the parietal regions resulted in some suppression of visual information in a similar time frame, but the effects were less pronounced and more intermittent than with occipital TMS. Together, these data suggest that both the occipital and the parietal cortex may play an important role in stimulus visibility.

33.327 **The P300 is an electrophysiological correlate of semantic similarity** 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

Previous work using simple stimuli argued that the P300 can serve as an index of visual similarity (e.g. Azizian, Freitas, Watson, & Squires, 2006), but this work did not rule out the possibility that semantic similarity masqueraded as visual similarity. Does the P300 provide a neural indicator of semantic similarity? To answer this question, we collected visual and semantic similarity ratings between a target category of objects (butterflies) and 2,000 random category nontargets. ERPs were recorded during a foveal discrimination task: Subjects identified via button press whether each of 950 images—displayed sequentially—was a butterfly (1/5th of trials) or not. Nontarget items were selected to be either: semantically but not visually similar to butterflies, visually but not semantically similar to butterflies, dissimilar on both ratings, or similar on both. We found that P300s had larger amplitudes for semantically-similar and both-similar nontargets compared to visually-similar and both-dissimilar nontargets. In a control experiment, subjects were shown the identical images but were told to give the same speeded response to every object regardless of its category. Under these conditions, the P300 was unaffected by visual or semantic similarity, consistent with similarity being no longer task relevant. This demonstrates that the modulation of the P300 was due to semantic similarity between targets and nontargets, and not simple item effects. In conclusion, we demonstrated a clear relationship between the P300 and semantic similarity using realistic objects, but not visual similarity as had been previously suggested in the context of simpler stimuli. Our findings also extend work showing P300-like responses during viewing of scenes with semantic inconsistencies (Ganis & Kutas, 2003), suggesting that the P300s preceding N400s in scene viewing may reflect the establishment of semantic relationships and not merely infrequency of incongruities or surprise caused by incongruity.

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33.328 **Expectation induced curvature perception in V2** Carmel Mevo[1](c.mevorach@bham.ac.uk), Zoe Kourtzi[1], Yehoshua Tsal[2]; [1]School of Psychology, University of Birmingham, UK, [2]Psychology department, Tel Aviv University, Israel

According to hierarchical models that advocate cognitive impenetrability, early visual processing feeds into conceptual systems, but the latter do not influence visual processes (e.g., Pylyshyn,1999; Riesenhuber & Poggio, 2000). In contrast, according to interactive views low-level visual representations are constantly influenced by higher-level representations, leading to activity that is context dependent (e.g., Di Lollo, Enns & Rensink, (2000);

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Lamme &Roelfsema, (2000); Tsal & Avital, 2012). Here we explore early brain structures potentially subject to top down context effects by examining neuronal responses to curvature for non-curved angular stimuli, the perceptual representation of which is induced with curvature by top down processes of context and expectation. Using fMRI we have recorded early visual cortex (V1, V2, V3 , V4) responses under three conditions; (a) The Curved Condition presented with random repetitions of: 0, 2, 3, 6, 8 and 9, including primarily curved features. The Angular Condition presented the same digits in a digital format including only non-curved angular features. The Shape Condition presented repetitions of 6 nonsense figures, each obtained by shifting or relocating one feature in each of the angular digits. Contrasting activity for the Shape and Curved conditions revealed extensive activation in V1 reflecting the physical difference between the two categories. Most importantly, contrasting activation for the Digital and Shape conditions revealed unique activation within V2. As the low-level bottom-up features of the two display categories were identical we conclude that this V2 activation can only reflect top-down processes that effect perceptual processes in early visual cortex. As V2 in particular has been associated with curvature processing (e.g., Hedge & Van Essen, 2000) we suggest that its activation here reflects context induced curvature perception. These results provide support of cognitive penetration and to the notion that categorical perception results from the modulation of very early visual representations by higher-level conceptual representations.

33.329 **Brain of myopes dealing with blur** Konogan BARANTON[1](barantok@essilor.fr), Thien Huong NGUYEN[2], Jean - Louis STIEVENART[2], Céline CAVEZIAN[3], Guillaume GIRAUDET[1,4]; [1]Essilor R&D Laboratories, Paris, France, [2]Department of Neuro - Imaging, Centre Hospitalier National d'Ophtalmologie des XV - XX, Paris, France, [3]Laboratoire VAC - EAU 01, Université Paris Descartes, Boulogne-Billancourt, France, [4]Essilor CANADA

Myopes and emmetropes present behavioural differences in presence of blur, whether in detection, tolerance and performance (Rosenfield and Abraham-Cohen, 1999). The purpose of our study was to compare the cortical response in myopes and in emmetropes when exposed to altered image resolution. We explored 38 young adults aged from 18 to 35 years including 18 emmetropes and 20 corrected myopes through functional M.R.I. at 3 Tesla. Cortical response was registered while subjects observed boards of optotypes, made of isolated Sloan letters. We add a simulated blur of 2 diopters (3.5 cycle/deg cut-off) for at least 12 second, and then images became progressively sharp. To maintain subject's attention, the task was to detect changes in blurriness. Reaction time was recorded. Data were analysed with SPM8 package. Functional series were coregistered with anatomic data acquisition, realigned, time corrected and normalized onto MNI. At group level, a random effect was performed using an individual t-contrast ($p < 0.001$ uncorrected). Behavioural data showed a quicker reaction for myopes than emmetropes (849ms vs. 1087ms, $p=0.024$). Global results showed similar responses in emmetropes and myopes in dorsal and ventral path with a predominance of the right hemisphere. Statistical comparison showed mild but significant differences between the two groups, the myopes presenting more activation in right middle temporal (BA21, 12 voxels, $F=10.11$), left putamen (5 voxels, $F=8.57$), right caudate nucleus (5 voxels, $F=8.51$) and right superior frontal area (5 voxels, $F=8.09$) when compared to emmetropes. The predominance of right hemisphere might be linked with a specialisation for low spatial frequencies (Peyrin et al., 2010). Differences between two groups suggest a cortical adaptation in myopes in accordance with a fastest detection of blur variation, recruiting supplementary areas distant from occipital lobe to enhance altered image perception.

33.330 **Rapid object recognition in the absence of conscious awareness** Weina Zhu[1,2](zhuweina_xm@sina.com), Jan Drewes[3], Yue Li[1], Karl R. Gegenfurtner[4]; [1]School of Information Science, Yunnan University, China, [2]Kunming Institute of Zoology, Chinese Acad. of Science, China, [3]Centre for Vision Research, York University, Toronto, Canada, [4]Department of Psychology, Giessen University, Germany

The visual system has a remarkable capability to extract categorical information from complex natural scenes (Thorpe, Fize et al. 1996). To investigate whether rapid object recognition is limited to conscious perception, we recorded event-related potentials (ERPs) on both conscious and unconscious conditions. A continuous flash suppression (CFS) paradigm was used to ensure the target image was suppressed during the experiment (Tsuchiya and Koch 2005), in which the target was displayed in one eye to compete against flashed masks presented to the other eye. We equated the luminance and contrast of the images by using the SHINE toolbox to minimize potential low-level confounds in our study (Willenbockel, Sadr et al. 2010). In experiment 1, the duration of suppression was measured during CFS. We found animal images to be perceived earlier than non-animal under identical suppression masking (1666ms vs. 1728ms). This suggests a privileged processing of animal images exists even during suppression. In experiment 2, image contrast was adaptively controlled to ensure 50% of the images were seen during CFS. Subjects were to decide/guess the presence of an animal in the shown images. Accuracy was 77% vs. 49% for "seen" and "unseen", confirming subjects were truly unaware of "unseen" images. ERP results showed animal images induced bigger amplitude (150ms-350ms) than non-animal images on "seen" condition, but smaller amplitude than non-animal images on "unseen" condition ($p(animal\times seen) = 0.034$). The amplitude of animal images was significantly different between seen and unseen condition ($p=0.011$), but not for the non-animal images. The trial-by-trial correlation between seen/unseen condition and EEG amplitude for both animal and non-animal images is significant before 380ms ($p<0.05$). Our results indicate the brain has different responses on animal and distractor (non-animal) images even in unawareness, and the rapid processing of animal images might be different in conscious and unconscious conditions.

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Eye Movements: Cognition, models

Sunday, May 12, 8:30 am - 12:30 pm

Poster Session, Orchid Ballroom

33.401 **Investigating the role of event structure and task goals on oculomotor behaviour and change blindness when observing CCTV footage.** Gemma Graham[1](gemma.graham@port.ac.uk), Anne Hillstrom[1], James Sauer[1], Jenny Page[2]; [1]Department of Psychology, University of Portsmouth, [2]Department of Sport and Exercise Science, University of Portsmouth

Change-detection (CD) studies and eye-tracking studies have largely used static images rather than videos as stimuli; adding dynamism allows investigation of the influence of an unfolding event on behaviour. The study reported here is the first of a series investigating how task goals and the nature of the event in the video affects CD and the way people inspect one kind of video: CCTV footage. Two 2-minute videos, matched except for a critical 10 sec, showed a waiting room with views alternating between two cameras' viewpoints every 5 sec. In one video a crime occurred (theft of a dropped phone); in the other, no crime occurred, and so there was less of a plot. In both videos, a target change occurred starting concurrent with the start of the crime: two people depicted in different camera views switched locations. One of those two people was the thief in the crime video. Fifty participants were instructed to look for a crime; fifty to look for something unusual occurring and fifty simply to watch the video. Eye movements were recorded. CD (24% overall) was unaffected by event type and task instruction. Eye movements, however, were affected by both factors and by whether or not a change was detected. Observers looking for a crime made more fixations on the thief and fixations of shorter duration overall than other observers. Observers of the crime video made fewer fixations before the crime and fixated the thief more during the crime than other observers, particularly when looking for a crime. Participants demonstrating CD had longer fixations on the people who changed before, during and after the change. They made more fixations and for longer durations, which we interpret as indicating more cognitive processing. Future studies will dissociate the change from the crime both spatial and temporally.

33.402 **The Influence of Salient Distractors over the Course of a Category Learning Task** Caitlyn McColeman[1](caitlyn_mccoleman@sfu.ca), Mark Blair[2]; [1]Department of Psychology, Simon Fraser University, [2]Cognitive Science Program and Department of Psychology, Simon Fraser University

Understanding the relative contributions of goal-directed and stimulus-responsive attention is a critical problem in visual cognition. To pit the two processes against one another, we develop an experiment where both are elicited by the task structure and the stimulus set, respectively. Specifically, we aim uncover the relative influence of salient, distracting information while participants learn how to sort visual stimuli into four different categories using less salient, but informative features of the stimulus. In this regard, we can examine both learned goal-directed attention and reflexive, stimulus-responsive attention to salient distractors simultaneously, thereby examining their interactions over learning. The 3 informative features of the stimulus are learned through trial-and-error. The salience condition presents irrelevant features that act as salient distractors; and the irrelevant features in the baseline condition are all equally non-salient. In contrast with predictions from theories of salience in visual attention, we

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find that those in the salient condition display more efficient eye movements by minimizing fixations to unimportant features relative to the baseline condition as measured by an optimization score (Blair, Watson & Meier, 2009) that reflects the proportion of fixations allocated to informative versus irrelevant features. Findings suggest that theories predicting eye movements from bottom-up information do not wholly account for oculo-motor activity during category learning problems of this nature. However, salience must enact some influence on the programming of saccades, otherwise both conditions would exhibit a similar optimization score. Our interpretations of these data are: 1) in the short duration preceding a saccade, goal-directed and stimulus-responsive attention both act to influence the selected saccade target; and 2) hybrid theories of goal-directed/stimulus-responsive processes provide the most plausible account of attention as it is observed in eye movements during a learning task.

Acknowledgement: NSERC, CFI

33.403 Eye movements during working memory retention period influence performance

Zhenlan Jin[1](jinzl@uestc.edu.cn), Yu Wang[1], Ling Li[1]; [1]Key Laboratory for NeuroInformation of Ministry of Education, School of Life Science and Technology, University of Electronic Science and Technology of China

Previous study showed refixations on an object help to remember it when freely inspecting a scene. The current study investigated whether eye locations after the stimuli offset still affect the performance of working memory (WM). Subjects were required to remember colors of 2 or 4 squares at the cued visual field (left or right) and foveate on a fixed (fixating condition) or moving (pursuing condition) cross for 2 seconds after the colored squares disappeared. In the pursuing condition, the cross moved towards or away from the cued visual field. After this 2 s of retention period, a test display with the same number of squares appeared and the subjects were required to judge whether the color of squares changed. Consistent with other studies, the WM performance showed lower accuracy and longer reaction times as the number of squares increased. Pursuing the cross did not weaken the WM performance compared to fixating the cross. However, the WM accuracy was higher when the cross moved towards the cued visual field compared to when the cross moved away from the cued visual field. This might be related to the attention allocation during smooth pursuit that more attention is distributed ahead of pursuit target. In summary, these results suggest that eye movements during the retention period affect the WM performance.

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33.404 Cueing vs. familiarity: an eye movement study of colour-form binding through stored knowledge

Giles Anderson[1](giles@gilesanderson.co.uk), Glyn Humphreys[2]; [1]Psychology, Health and Life Sciences, Oxford Brookes University, [2]Department of Experimental Psychology, University of Oxford

Previous research (Rappaport, Humphreys, & Riddoch, in press) has suggested that objects automatically co-activate the colour habitually assigned to them, such that a difficult search for an object in its familiar colour is quicker and more efficient than when its colour is unfamiliar. We investigate how cueing the colour of the target interacts with this search advantage. Uncued search for a shape singleton (a yellow or purple coloured corn target amongst aubergine distractors, half of which were yellow, half purple) was followed by cued trials in which the target colour was predicted at 80% validity. In the uncued block, search was faster and more efficient when the search-irrelevant colour of the target was familiar. Following this, valid cues facilitated search while invalid cues slowed RTs, but only the slope for targets in incorrect colours was affected. Eye-tracking data indicated that, on uncued search, participants frequently fixated distractors with the familiar colour of the target, while more initial eye movements were directed to targets carrying their familiar rather than an unfamiliar colour. In contrast, cues directed first fixations to items with the cued colour. Despite this, there was no effect on the efficiency of search for an uncued target carrying its familiar colour. The data are consistent with attention being attracted in a bottom-up manner to targets in their correct colour, along with target identification being facilitated to correctly coloured objects. Rappaport, S. J., Humphreys, G. W., & Riddoch, M. J. (in press). The Attraction of Yellow Corn: Evidence for Spatially Parallel Binding of Learned Conjunctive Relations. Journal of Experimental Psychology: Human Perception and Performance.

33.405 Eye movements in the number connection test: Evidence for long-term memory based control of visual selection in a sequential sensorimotor task

Rebecca M. Foerster[1,2](rebecca.foerster@uni-bielefeld.de), Werner X. Schneider[1,2]; [1]Neurocognitive Psychology, Bielefeld University, [2]Cluster of Excellence 'Cognitive Interaction Technology', Bielefeld University

Humans perform task-dependent eye movements when engaged in well-learned actions. Especially in sequential sensorimotor tasks, systematic scan paths can be observed with fixations guiding the hands to upcoming target locations. A recent study of our lab [Foerster et al., 2012] provided first evidence that this eye-hand guidance can even be observed when no visual information is available. This result argues for a long-term memory (LTM) contribution to the control of covert attention and eye movements in naturalistic tasks. To test this idea with a higher degree of experimental control, we investigated eye movements while participants performed a computerized version of the number connection test. In this sequential sensorimotor task, participants have to click as fast as possible on numbered circles in ascending order (1 – 9). During an acquisition phase, participants performed the task for 50 trials with the same spatial arrangement of 9 circles. With practice, participants became faster and performed fewer fixations. Eye-hand time spans were mainly positive throughout the experiment. In the consecutive retrieval phase, a blank screen appeared and participants were asked to click on an empty screen in the same order as during acquisition phase. Participants were able to perform this complex sequential sub-task and looked often in the right order at upcoming circle locations before clicking on them. We conclude that practice of a sequential sensorimotor task such as the number connection test does not only imply LTM-based control of sequential hand movements but is also accompanied by learning of systematic sequences of attention shifts and eye movements. These sequential selection patterns can also be reproduced from LTM when visual information is no longer available.

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33.406 Visual task-switching: No cost for switching to search

Mark Mills[1](mark.mills2@huskers.unl.edu), Michael Dodd[1]; [1]University of Nebraska-Lincoln

Successful interaction with complex scenes requires the ability to switch efficiently from one visual behavior (searching for an item) to another (memorizing location of an item). Though it is established that task-set influences the location and timing of eye movements during scene perception, the impact of switching task-sets on visual behavior is less clear. For instance, whereas manual responses are associated with large performance costs when switching tasks, oculomotor responses often are not associated with a residual cost and, in fact, can even show a paradoxical switch-benefit with sufficient preparation (Hunt & Klein, 2002). The purpose of the present study was to examine the influence of task-switching on saccade amplitude and fixation duration while viewing natural scenes. Scenes were colored photographs of forests and mountains. Participants were cued to perform discrimination (mountain/forest) and search (man-made-object present/absent) tasks in a mixed-task block, with either a 300 or 900 ms preparation interval. Switch-cost asymmetries were observed in the RT and saccade amplitude data such that large switch (and residual) costs were observed for the discrimination task, whereas no switch costs were observed for the search task (a switch benefit was observed for both outcomes at the 900 ms interval). Switch costs on fixation duration were observed for both tasks. However, whereas there was a residual cost associated with discrimination, there was not a residual cost associated with search. Finally, a multilevel multivariate difference score analysis indicated that fixation duration and saccade amplitude significantly predicted RT performance such that longer durations and smaller amplitudes were associated with better performance on the discrimination task, whereas the opposite was true for the search task. Interestingly, the magnitude of the amplitude effect on performance was larger than the fixation duration effect. Taken together, these results suggest that switch costs may be offset by improved saccade control.

33.407 Distinct stages of word identification during reading: Evidence from eye movements

Heather Sheridan[1](heather.sheridan@mail.utoronto.ca), Eyal M. Reingold[1]; [1]Department of Psychology, University of Toronto at Mississauga

The present study was designed to examine the processes underlying word identification during reading, by manipulating both lexical and visual aspects of the text. Specifically, participants' eye movements were monitored while they read sentences in which high-frequency and low-frequency target words were presented either normally (i.e., the normal condition) or with reduced stimulus quality (i.e., the faint condition), or with alternating lower and upper case letters (i.e., the case alternated condition). Both the stimulus quality and case alternation manipulations interacted with word frequency for the gaze duration measure (i.e., the cumulative duration of all first-pass fixations on the target word), such that the magnitude of word frequency effects was increased relative to the normal condition. However, stimulus quality (but not case alternation) interacted with word frequency for the early fixation time measures (i.e., first fixation, single fixation), whereas case

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alternation (but not stimulus quality) interacted with word frequency for the later fixation time measures (i.e., total time, go-past time). We interpret this pattern of results as evidence that stimulus quality influences an earlier stage of lexical processing than case alternation, and we discuss the implications of our results for models of eye movement control during reading.

Acknowledgement: This research was supported by an NSERC grant to Eyal M. Reingold.

33.408 **Spatial Bias induced by Semantic Valence: Evidence From Eye Movement Trajectories** Davood Gozli[1](d.gharagozli@mail.utoronto.ca), Amy Chow[1], Alison L. Chasteen[1], Jay Pratt[1]; [1]Department of Psychology, University of Toronto

Concepts of positive and negative valence are metaphorically structured in space (e.g., happy is up, sad is down). In fact, coupling a conceptual task (e.g., evaluating words as positive or negative) with a visuospatial task (e.g., identifying stimuli above or below fixation) often gives rise to metaphorical congruency effects. For instance, after reading a positive concept, a visual target above fixation is processed more efficiently than one below fixation. Recent studies, however, have challenged the idea that up and down spatial codes are automatically activated by valence concepts. Instead, it is possible that tasks requiring upward and downward attentional orienting artificially emphasize the link between valence and space. Here, we address the question as to whether the up and down spatial codes can be activated in a task that does not require attentional orienting along the vertical axis. To uncouple the valence axis from the spatial response axis we measured saccadic trajectory deviations, with the assumption that fast saccades deviate toward the salient segment of space. Participants read a single word at fixation, referring to a positive (e.g., 'happy'), negative (e.g., 'sad'), or neutral concept (e.g., 'table). A peripheral visual target then appeared to the left or right, and participants made speeded saccadic responses to the target (unless the preceding word referred to a piece of furniture). Examining saccadic trajectories revealed patterns of deviation along the vertical axis consistent with the metaphorical congruency account; larger saccadic deviations upward were found after positive concepts compared to negative concepts. Importantly, placing task-irrelevant distractors above and below fixation did not modulate the pattern of deviations. These results suggest that metaphorical congruency effects between valence and space are not an artificial product of specific experimental tasks. That is, semantic processing of valence may automatically recruit spatial features along the vertical axis.

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33.409 **The Influence of Scene Context on Parafoveal Processing of Objects** Effie Pereira[1](effie.pereira@queensu.ca), Monica Castelhano[1]; [1]Department of Psychology, Queen's University

Previous research in reading has shown that information about a word is obtained from the parafovea before it is directly fixated, which speeds the processing of that word once it is subsequently fixated (Rayner, 1975). Further research has shown that contextual constraints (e.g. the predictability of a word) lead to an increase in information acquired from the parafovea (Balota, Rayner & Pollatsek, 1985; McClelland & O'Regan, 1981). Studies have also shown similar effects of contextual constraints on the processing of objects (Biederman, Mezzanotte & Rabinowitz, 1982; Henderson & Hollingworth, 1998). In the present study, we examine whether scene context constrains parafoveal processing of objects prior to fixation. Participants were shown a preview of the target object at either 4° (parafovea) or 10° (periphery) from the point of fixation in either a consistent or inconsistent scene context. The preview could be: (i) identical to the target; (ii) a different category with the same shape; (iii) a different category and different shape; or (iv) a black rectangle control. During the saccade towards the preview object, it changed to the target. In Experiment 1, participants had better performance for identical and similarly-shaped previews, with a stronger benefit for consistent contexts. In Experiment 2, participants had to verify whether the target matched a given object name seen before the trial commenced. Results showed a higher sensitivity (A-prime) for consistent vs. inconsistent contexts. In Experiment 3, participants verified the object name at the end of the trial. The added uncertainty of the target identity led to no difference in sensitivity between context conditions, but did demonstrate a difference in bias (B''D) toward 'yes' responses between consistent and inconsistent scene contexts. Across the three experiments, we show that scene context does have a constraining effect on preview processing of objects prior to fixation.

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33.410 **The effects of task and uncertainty on gaze while walking** Matthew Tong[1](mhtong@utexas.edu), Mary Hayhoe[1]; [1]Department of Psychology, University of Texas at Austin

Human beings in the natural world must simultaneously perform a range of tasks, each of which may rely on different information from the scene. Eye movements are an important way of gathering necessary information, and the timing and choice of targets for gaze is critical for efficiently performing tasks. Sprague et al. (2007) proposed a model of gaze deployment based on the rewards and uncertainty associated with the tasks at hand. We have designed a novel virtual reality environment that allows us to systematically vary both the task rewards and the uncertainty of the information for each task. Subjects traverse the room on a path, while contacting targets (bubbles) and avoiding obstacles (pigeons). Location information is made more uncertain by having targets and obstacles move and (in future work) varying the complexity and contrast of the path. The system also allows us to record simultaneously how people orient their bodies, heads, and eyes, all of which play a role in directing gaze. We manipulate the task structure by independently varying the tasks subjects are asked to perform and the uncertainty of the world. While on all trials subjects followed the path, on different trials they were asked to contact bubbles, avoid pigeons, do both, or do neither. This allows us to examine how task priorities are managed under different conditions. Consistent with other work (e.g., Rothkopf et al., 2007), we see strong variations of fixations as the task structure is altered; trials on which subjects did not need to avoid pigeons showed a marked decrease in fixations to pigeons, for instance, despite their image salience remaining unchanged. We also find preliminary evidence that our uncertainty manipulation affects subjects' allocation of task priorities - this may necessitate revisions to the assumptions of the Sprague model.

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33.411 **Target relevance modulates primate gaze behavior during natural scene search** Pavan Ramkumar[1](pavan.ramkumar@northwestern.edu), Hugo Fernandes[1,2], Mark Segraves[3], Konrad Kording[1]; [1]Department of Physical Medicine and Rehabilitation, Northwestern University and Rehabilitation Institute of Chicago, Chicago, Illinois, U.S.A., [2]PDBC, Instituto Gulbenkian de Ciência, Oeiras, Portugal, [3]Department of Neurobiology, Northwestern University, Evanston, Illinois, U.S.A.

When viewing natural images, primates fixate locations of interest. In particular, both bottom-up saliency (e.g. contrast) and top-down target relevance influence where to look next. Computational models that take both saliency and relevance into account, predict fixations better than those based on saliency alone. While previous studies have analyzed the effect of relevance, in these studies both feature-based and location-based attention could have influenced search behavior. Here, to focus on feature-based attention alone, we designed a search task that does not have any spatial cues; two macaque monkeys searched for a 2˚ x 2˚ vertical Gabor target placed randomly (uniformly) within human-photographed scenes. The data comprised ~11,000 fixations spanning ~1600 different image searches. We then asked (1) how well relevance predicts gaze and (2) what features the fixated image patches shared with the target. First, to quantify how well relevance predicts gaze, we defined relevance of a fixated image patch as the maximum of the convolution of the fixated image patch with the target Gabor wavelet. We found that across all fixations (excluding the last), the monkey fixated at locations that were more relevant than predicted by chance (Area under ROC, or AUC=0.66 and 0.65 vs. shuffle predictor, for monkeys 1 and 2). Furthermore, relevance predicted fixations far better than the Itti-Koch saliency model (AUC=0.51 and 0.50, $p<0.001$). This result suggests that monkeys preferentially fixate task-relevant locations, and this behavior supersedes the effect of other salient locations. Second, we quantified the similarity between target and fixated image patches by examining their spectral properties. We found that the fixated patches have higher energy than patches of shuffled images, in particular, along the relevant orientation. This result shows that monkeys tend to fixate at locations sharing spectral properties with the target.

33.412 **Perceptual brightness decisions do not use a difference model** Dorion Liston[1,2](dorion.b.liston@nasa.gov), Leland Stone[1]; [1]NASA Ames Research Center, Moffett Field, CA, [2]San Jose State University, San Jose, CA

Many current models of perceptual decision-making utilize a single decision variable encoding the difference between two alternate signals to account for behavioral data, often implemented as a log likelihood ratio. Alternatively, such data can be modeled using a "race" mechanism in which two separate decision variables, encoding each of the alternatives, race against one another in parallel. Consider a generic magnitude discrimination between two signals, a and b. In the noise-free case, these two models predict identi-

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cal sets of choices (i.e., a-b>0 and a>b are canonically equivalent), but qualitatively distinct relationships between perceived stimulus magnitude and the respective signal strengths of the selected and unselected stimuli. In particular, a difference model predicts strong mirror image correlations of equal magnitude and opposite sign between the selected and unselected signal strengths (because of the equal and opposite weighting in a simple difference). On the other hand, the race model predicts correlations of unequal strength (and both typically positive) between perceived stimulus magnitude and the respective signal strengths of the selected and unselected stimuli (because a race produces positive competition between the two signals). Methods. We used a two-stage task in which observers (n=5) made saccadic choices in a 2AFC spatial brightness discrimination task and then reported the perceived brightness of the selected stimulus using method of adjustment. We compared the reported brightness value to the absolute signal strength of each alternative stimulus. Results. We observed positive correlations between perceived brightness and both the selected and unselected stimulus strength for all observers (bootstrap test, p<0.01). However, we simulated the difference mechanism with three commonly-used sources of internal noise (Brownian, Carpenter, and baseline-to-threshold), and were unable to break the equal and opposite correlation predictions. Conclusion. We conclude that no difference (or log likelihood ratio) model can account for the observed patterns of perceptual performance.

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33.413 **Probing Attention in the Human Superior Colliculus** Javier Lopez-Calderon[1](javlopez@ucdavis.edu), Steven J. Luck[1]; [1]Center for Mind and Brain, University of California, Davis

The superior colliculus (SC) clearly plays a role in spatial attention in non-human primates, but the SC is a small, deep structure that is difficult to study in humans. However, it is possible to isolate SC-related processed by using monocular stimulation, because only the contralateral nasal hemiretina projects to the SC on a given side. Consequently, monocular presentation to the nasal versus temporal hemiretina of a given eye will cause the contralateral SC to be stimulated versus not stimulated. The present study adopted this approach using anaglyph lenses to control the eye of stimulation, in an oculomotor inhibition of return (IOR) task, making it possible for the first time to independently control the hemiretina of the cue and target . Each trial contained a cue in one of the four quadrants and then a target at the cued location or at one of the uncued locations, with no predictive relationship between the cue and target locations. Observers were instructed to make a rapid saccade to the target location. In a sample of 11 observers (24±5 years old), we found that IOR was significantly larger when both the cue and target were directed to the nasal hemiretinae compared to any other combination. This indicates that the SC plays a significant role in IOR, and it establishes a method that can be used in future research to determine the nature of the SC contribution to attentional orienting.

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33.414 **Oculomotor strategies for rapid identification of large visual stimuli** Anna Montagnini[1](anna.montagnini@univ-amu.fr), Jonathan Mirault[1], Laurent Madelain[1,2]; [1]Institut de Neuroscience de la Timone, CNRS & Aix-Marseille University, France, [2]Psychology, Ureca - Univ. Lille 3, Villeneuve D'Ascq, France

Directing gaze toward different parts of a visual image enhances the visual processing of these selected regions. A straightforward hypothesis is that efficient saccadic eye movements select regions that maximize the information, or, equivalently, minimize entropy, relative to the image and the task at hand. However, in unconstrained visual exploration the definition of a functional utility function (the information that has to be maximized) is very complex. In addition, previous studies using well defined hard tasks (a visual search and a visual template-matching task respectively) have shown that the pattern of free fixation selections may maximize either the global, task-related information (Najemnik and Geisler 2005) or the local image-specific information (Renninger et al. 2007). To further elucidate the process underlying efficient fixation selection, we used a simplified experimental design. We recorded saccadic eye movements and perceptual performance in a visual 4AFC identification task in which large composite stimuli (i.e. non resolvable within one single fixation) were presented for 500ms, a duration which typically allows a maximum of two distinct fixation periods. Results suggest that subjects tend to adopt globally optimal strategies for fixation selection, minimizing the entropy related to stimulus identity. When several alternative strategies lead to entropy minimization, one scheme of fixation selection is maintained throughout the task (possibly the one minimizing motor effort). Furthermore, we observed that a bias in the probability of occurrence of specific stimuli did not affect oculomotor strategies except when it modified the spatial distribution of the maximally informative regions. Finally, we compared the perceptual performance in the free-gaze identification task with a model of strictly sequential static identification of local elements (as though at each fixation, only the element closest to gaze location was processed). Surprisingly, the performance in the free-gaze task was in general below that prediction. Possible explanations are discussed.

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33.415 **Modified visuomotor optimization theory to explain Listing's Law** Sarah Marzen[1,3](smarzen@berkeley.edu), Joel Zylberberg[2], Mike DeWeese[1,3,4]; [1]Department of Physics, U.C. Berkeley, [2]Department of Applied Mathematics, U. Washington, [3]Redwood Center for Theoretical Neuroscience, U.C. Berkeley, [4]Helen Wills Neuroscience Institute, U.C. Berkeley

There are an infinite number of ways that our eyes could rotate in order to fixate on a point in visual space, but humans' eyes consistently choose rotation axes that lie in head-fixed ``Listing's planes''. Not only are these planes always exorotated relative to planes that lie flat against the head, but the orientation of these planes changes systematically with fixation point. Previous investigators have tried to quantitatively explain the existence and orientation of these planes for centuries, and the current visuomotor optimization theory explains the systematic variation of Listing's plane orientation with changes in fixation point. However, when this visuomotor optimization theory is evaluated carefully using a more recent understanding of naturalistic fixation point distribution, it cannot explain the exorotation of Listing's planes during viewing of far-away objects. We develop a new visuomotor optimization theory that balances metabolic energy expenditure of both our eye musculature and the axons of interneuronal neurons in V1 against our ability to fuse the two disparate retinal images. The former factor is crucial for understanding the systematic variation of Listing's plane orientation upon viewing nearby objects, and the latter factor is crucial for understanding Listing's plane exorotation when viewing far-away objects.

33.416 **Statistics of spatial-temporal concatenations of features at human fixations in action classification** Xin Chen[1,2](chenxincx@gmail.com), Xiaoyuan Zhu[1,2], Weibing Wan[4], Zhiyong Yang[1,2,3]; [1]Brain And Behavior Discovery Institute, Georgia Health Sciences University, [2]Vision Discovery Institute, Georgia Health Sciences University, [3]Department Of Ophthalmology, Georgia Health Sciences University, [4]Department Of Automation, Shanghai Jiaotong University

Humans can detect, recognize, and classify a range of actions quickly. What are the spatial-temporal features and computations that underlie this ability? Global representations such as spatial-temporal volumes can be highly informative, but depend on segmentation and tracking. Local representations such as histograms of optic flow lack descriptive power and require extensive training. Recently, we developed a model in which any human action is encoded by a spatial-temporal concatenation of natural action structures (NASs), i.e., sequences of structured patches in human actions at multiple spatial-temporal scales. We compiled NASs from videos of natural human actions, examined the statistics of NASs, and selected a set of NASs that are highly informative and used them as features for action classification. We found that the NASs obtained in this way achieved a significantly better recognition performance than simple spatial-temporal features. To examine to which extend this model accounts for human action understanding, we hypothesized that humans search for informative NASs in this task and performed visual psychophysical studies. We asked 12 subjects with normal vision to classify 500 videos of human actions while tracking their fixations with an EyeLink II eye tracker. We examined statistics of the NASs compiled at the recorded fixations and found that human observers' fixations were sparsely distributed and usually deployed to locations in space-time where concatenations of local features are informative. We selected a set of NASs compiled at the fixations and used them as features for action classification. We found that the classification accuracy is comparable to human performance and to that of the same model but with automatically selected NASs. We concluded that encoding natural human actions in terms of NASs and their spatial-temporal concatenations accounts for aspects of human action understanding.

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33.417 Perisaccadic predictive remapping: a neural model of thalamo-cortical interactions Nan Jia[1,2](pacificmyth@gmail.com), Arash Yazdanbakhsh[1,2]; [1]Center for Computational Neuroscience and Neural Technologies, Boston University, [2]Program in Cognitive and Neural Systems, Boston University

Neurophysiology studies have identified neurons in the oculomotor system that remap their receptive fields (RFs) around the time of saccade, which has been thought to have a potentially important role in shaping perisaccadic visual perception (Melcher and Colby, 2008). However, conflicting reports exist, in which some indicate that these remapping neurons gain response to visual stimulus presented at the new location in the visual field displaced in parallel with the saccade vector in Lateral Intraparietal area (LIP, Duhamel et al., 1992) and Frontal Eye Field (FEF, Sommer and Wurtz, 2006) while other reports show those neurons shift their RFs towards the saccade target in a compressive and convergent manner in area V4 (Tolias et al, 2001), FEF (Zirnsak et al., 2012). More importantly, Sommer and Wurtz (2006) showed the remapping activity in FEF was linked to corollary discharge (CD) relayed from superior colliculus (SC) via mediodorsal thalamus (MD). Here, we model single neuron receptive field remapping with a neural model using known anatomical pathways between SC, MD, and FEF. Our model indicates that using basic anatomical connections between these areas with a generic inter-areal on-center off-surround structure, is sufficient to yield RF remapping observed in single-cell studies, while compressive patterns of activity follows naturally from such architecture and its temporal dynamics. More specifically, the spatiotemporal interaction between the corollary discharge and signals that indicate fixation within the thalamo-cortical loop of the model plays a key role in achieving RF remapping. The model suggests reciprocal thalamo-cortical connections effectively stretch the RF size, thus allowing remapping to occur in cells over longer cortical distances. Since the model has a very basic functional architecture, we suggest it can be generalized to other cortical areas that have similar connectivity with SC and thalamus.

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Visual search: Eye movements

Sunday, May 12, 8:30 am - 12:30 pm

Poster Session, Orchid Ballroom

33.418 Visual search in natural scenes: efficient allocation of fixations to horizontal support surfaces Elan Barenholtz[1](elan.barenholtz@fau.edu), Brad Nemire[1]; [1]Dept. of Psychology, Florida Atlantic University

Previous research has found that visual search through natural scenes is surprisingly efficient and can be guided by semantically-based expectations about where particular objects are likely to be. In the current study, we examined whether people efficiently allocate attention to horizontal support surfaces, where objects are likely to be present . Participants were presented with photographs of unfamiliar indoor scenes (e.g. bedrooms, kitchens, etc..) and had to report, as quickly as possible, the pointing direction of an arrow shape that that had been placed on a horizontal surface somewhere in the scene. We found that people efficiently directed their gaze to horizontal surfaces—while these surfaces made up less than 10% of the total area of the images, more than half of fixations fell within horizontal surfaces. These results were not well predicted by models of fixation that are based on bottom-up saliency; instead they suggest that people may have preattentive access to some types of surface orientation in natural scenes, which can serve to guide attentional fixation to the likely locations of objects.

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33.419 Different functional roles of dopamine and acetylcholine in visual selection: Simulations of visual search in Alzheimer's and Parkinson's Diseases. Eirini Mavritsaki[1,2,3](eirini.mavritsaki@bcu.ac.uk), Glyn Humphreys[2]; [1]Faculty of Education Law and Social Sciences, Birmingham City University, City North Campys, Perry Bar, Birmingham B42 2SU, UK, [2]Department of Experimental Psychology, University of Oxford, South Parks Road, OX1 3UD, UK, [3]School of Psychology, University of Birmingham, Edgbaston, Birmingham, B15 2TP, UK

Previous research has differentiated between the performance of Parkinson's and Alzheimer's disease patients in visual search task [1, 2]. While Alzheimer's patients show normal (parallel) search for feature targets, performance is impaired for conjunction targets. Parkinson's patients can show the opposite pattern. These deficiencies may relate to deficiencies in acetylcholine for Alzheimer's patients and dopamine for Parkinson's patients, though both forms of deficiency exist in both disorders. We examined the effects of altering these neurotransmitters through computational modelling using the spiking Search over Space and Time (sSoTS) framework previously used to simulate behavioural and fMRI data on visual search, along also with the effects of posterior parietal cortex damage [3, 4]. To simulate Alzheimer's disease we applied changes in the model based on acetylcholine depletion [5]. For Parkinson's disease we altered parameters responsible for dopamine depletion [6] . Using these changes, the model was able to simulate the double dissociation between feature and conjunction search. Simulated reductions in dopamine led to a loss of search guidance to salient targets whilst reductions in acetylcholine affected the ability to reject competing distractors. The results point to particular functional roles of the different neurotransmitters in visual selection. REFERENCES 1. Cormack, F., et al., International Journal of Geriatric Psychiatry, 2004. 19(8): p. 763-772. 2. Cossa, F.M., S. Dellasala, and H. Spinnler, Neuropsychologia, 1989. 27(6): p. 887-892. 3. Mavritsaki, E., et al., Psychological Review, 2011. 118(1): p. 3-41. 4. Mavritsaki, E., et al., Cognitive Neuropsychology, 2009. 26(4): p. 343-390. 5. Deco, G. and A. Thiele, European Journal of Neuroscience, 2009. 30(3): p. 347-354. 6. Rolls, E.T., et al., Nature Reviews Neuroscience, 2008. 9(9): p. 696-709.

33.420 The Effects of Target Typicality on Guidance and Verification in Categorical Search Justin T. Maxfield[1](jmaxfieldsbu@gmail.com), Westri Stadler[1], Gregory J. Zelinsky[1,2]; [1]Department of Psychology, Stony Brook University, [2]Department of Computer Science, Stony Brook University

How are effects of target typicality expressed in a categorical visual search task? Participants were cued with a basic-level category name, followed by a present/absent search display depicting five real-world objects. Images of targets were segregated into interleaved high-, medium-, and low-typicality conditions based on typicality ratings (1-7) obtained during pretest; distractors were from random non-target categories. Contrary to previous work (Castelhano, Pollatsek, & Cave, 2008), we found a significant effect of target typicality on guidance; targets were first fixated most frequently in the high-typicality condition, followed by medium- and low-typicality targets (all $p < .05$). As expected, typicality effects were also expressed in target verification; the time between first fixation on the target and the manual response was shorter for higher typicality targets (all $p < .05$). To test whether these typicality effects on guidance and verification might be mediated by the same underlying process, we trained linear SVM classifiers on the same target categories used in the search experiment. Using SIFT features and positive and negative samples from ImageNet, we obtained for each of the high/medium/low typicality targets probability estimates of category membership based on distances from the SVM classification boundaries. We found that mean classifier confidence not only increased with target typicality, but these mean classifier estimates also correlated perfectly with the average (over participants) time-to-target ($r = -.999$, $p = 0.028$) and target verification ($r = -1$, $p = 0.004$) measures obtained for each level of typicality. Our findings clarify previous work by showing effects of target typicality on both search guidance and verification. Moreover, the fact that a single classifier could be trained to predict these components of search further suggests that the target representation used to mediate guidance and recognition search decisions may be one and the same.

Acknowledgement: NIH Grant R01-MH063748

33.421 Relating peripheral processing ability to learning in a visual search task Kathryn Koehler[1](koehler@psych.ucsb.edu), Emre Akbas[1], Miguel P. Eckstein[1]; [1]Department of Psychological and Brain Sciences, University of California, Santa Barbara

Humans show large individual differences in peripheral processing ability on a variety of tasks (Strasburger, Rentschler, & Jüttner, 2011). Yet, little is known about how these individual differences in peripheral processing influence humans' perceptual learning ability. Here, we relate peripheral processing detection performance of individuals to their ability to optimize their eye movements and improve perceptual performance in a visual search task with uncertainty about the location of the target. Methods: We first measured observers' accuracy at detecting a vertically oriented Gabor target (8 cycles/degree) embedded in white noise at various eccentricities in the visual field (visibility map). Subsequently, observers participated in a yes/no search task (12 sessions of 100 trials) for a Gabor target (50% probability of target presence) embedded in a field (29.6°x 22.2°) of dynamic white noise. The target was located five degrees from initial fixation and appeared for 700ms. Participants performed the task with no knowledge about the target location, but were informed that, if present, the target would always appear at the same location. Results: Observers with high detectability (mean $d'=0.7\pm0.09$) of the target at 5° from central fixation showed the greatest perceptual performance improvement between the

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first and last 100 trials (change in proportion correct, ΔPC=0.43±0.04), the highest optimization in oculomotor planning (change in mean saccade end-point distance to target locations: Δdist=4.02±0.36°), and highest accuracy in their post-experiment explicit reports of the target location (distance of reported location from target=1.01±.27°). Observers with poorer peripheral processing at the target eccentricity (mean d'=0.11±0.11%, n=2) showed smaller improvements in perceptual performance (ΔPC=0.11±0.07), reduced optimization of their saccades (Δdist=0.30±0.05°), and lower accuracy in their post-experiment explicit report of the target location (distance from target=4.92±.04°). Conclusion: Our results suggest that differences in peripheral processing can affect an observer's ability to optimize their saccadic planning and hinder perceptual learning.
Acknowledgement: Grant EY-015925 from the National Institutes of Health to M.P.E.

33.422 **Towards a Better Understanding of Eye-Movement Strategies in Multiple Target Search** Christian P. Janssen[1](cjanssen@ski.org), Preeti Verghese[1]; [1]The Smith-Kettlewell Eye Research Institute

Introduction: Where do people look when searching for multiple targets under time pressure? Previous studies showed that when there are multiple targets, fixating the most uncertain location is most efficient, as it maximizes information gained. However, observers tend to use the sub-optimal strategy of fixating likely target locations (Verghese, 2012). We test the generality of this finding using a simpler task that predicts a stronger contrast in performance by the two alternative strategies. Method: Targets (vertical Gabors) occurred independently at each of 2 locations - 5 degrees left and right of center. Each location also had noise of low or high contrast. Two observers (one author; one participant with practice in other eye movement studies) reported the presence or absence of a target at each location. Brief presentation time (400 msec) typically allowed a single saccade. After stimulus presentation, observers manually selected target locations and received performance feedback for each location. Different strategies make different behavior predictions. The strategy favoring uncertain locations inspects high noise locations - independent of target presence. The strategy favoring likely target locations inspects target-present locations, particularly when targets are highly visible (i.e., in low noise). Results: One observer did not show a clear strategy preference. The other, practiced, observer fixated uncertain locations more frequently. In part this might be because eccentric targets were less visible for this observer, making saccades more informative. Nonetheless, it is important to note her clear preference for uncertain locations. Conclusion: These results contrast with findings that observers choose likely (not uncertain) locations when planning sequences of saccades. Rather, in our study one observer tended to fixate uncertain locations. This suggests that eye-movement strategies are not completely outside of cognitive control and that observers can be efficient in a simple task where they plan a single saccade.
Acknowledgement: Rachel C. Atkinson award to CPJ and R01 EY022394 to PV

33.423 **Eye movements during highly inefficient visual search: What determines search efficiency differences in blank trials?** Gernot Horstmann[1,2](gernot.horstmann@uni-bielefeld.de), Arvid Herwig[2]; [1]Center for Interdisciplinary Research, Bielefeld University, Bielefeld, Germany, [2]Department of Psychology, Bielefeld University, Bielefeld, Germany

Introduction. Some targets in visual search are more difficult to find than others; for example, a target which is similar to the distractors is more difficult to find than a target which is dissimilar to the distractors. A remarkable result is that efficiency differences manifest themselves not only in target trials but also in blank (target absent) trials. In fact, even physically identical displays are searched through with different efficiencies depending on the searched-for target (e.g., Horstmann, Lipp, & Becker, 2012; http://www.journalofvision.org/content/12/5/7.full). Obviously, this effect is not driven by the target but by the search template. Because the focus of models of visual search is on target trials, theoretical or empirical treatments of blank trials have been presented only sporadically. Eye movements are examined to explore three hypotheses concerning the causes of differential search efficiencies in blank trials: (a) distractor skipping regulated by a variable threshold, (b) rescanning, and (c) dwell times. Methods. Participants performed a very inefficient search for two types of emotional target faces among neutral distractor faces. Target-distractor similarity (TDS) was varied between blocks: while in the high TDS blocks, the target was similar to the neutral distractors, in the low TDS blocks, the target was dissimilar to the distractors. The distractors were the same in all blocks. Results. Visual search times differed between the high and the low TDS condition, replicating earlier results. Eye movements were analyzed for skipping of distractors, rescanning of distractors, and gaze dwell times. Results showed that differences in dwell time and rescanning account for most of the search time differences between high and low TDS blocks. Conclusion. Low search efficiency in blank trials of high TDS blocks is mostly due to prolonged dwelling and more frequent rescanning of distractors, at least for a very inefficient search.
Acknowledgement: Supported by CITEC (Cognitive Interaction Technology, Center of Excellence)

33.424 **Weakened Target Representations in Low Prevalence Visual Search** Hayward J. Godwin[1](hg102@soton.ac.uk), Tamaryn Menneer[1], Nick Donnelly[1]; [1]University of Southampton

We examined the strength of activation of different target templates during a dual-target visual search task. We manipulated the proportion of trials where each target was presented (known as the target prevalence) in order to assess whether target templates are shaped by regularities in the environment. We recorded participants' eye movement behaviour as they searched for two targets, one of which appeared on 45% of trials (TH) while the other appeared on 5% of trials (TL). We sought to determine whether guidance or identification processes (or both) were weakened by a reduction in target prevalence. Response accuracy data demonstrated that participants were less likely to detect TL than TH, replicating the prevalence effect. Analyses of eye movement behaviour indicated that guidance was weakened in low prevalence: participants were both less likely, and less rapid, to fixate distractors that shared their colour with TL than TH. Furthermore, identification processes in low prevalence search were also shown to be weakened, with the time between first fixating TL and responding 'present' being longer than the time between first fixating TH and responding 'present'. Taken together, these results demonstrate that low target prevalence weakens target templates, both for guidance and recognition. This finding accounts for previous results, in which participants to fail to detect low prevalence targets, by showing that participants are less likely to fixate target objects, and, when they do, more time is required in order to identify those objects.
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33.425 **Constant fixation strategies underlying visual search in natural scenes** David H. Foster[1](d.h.foster@manchester.ac.uk), Kinjiro Amano[1]; [1]School of Electrical & Electronic Engineering, University of Manchester, Manchester M13 9PL, UK

The distribution of fixations in natural scenes is difficult to predict. In free viewing, the proportion of variance explained by bottom-up scene effects is at best about 60%; in visual search, somewhat less. The remaining variance is usually attributed to the uncertain effects of search strategy and related cognitive factors. The aim here was to assess the variability of these top-down effects by comparing the distributions of first, second, and subsequent fixations in a difficult search task. Seven observers with normal color vision and visual acuity viewed repeated images of 20 natural scenes, each subtending 17x13 deg visual angle, displayed on a color monitor. The target was a shaded gray sphere subtending 0.25 deg, matched in mean luminance to its local surround and positioned randomly in the scene. In each trial an image appeared for 1 sec, after which the observer reported whether the target was present. Each observer performed 260 trials per scene, half containing the target and half not. Gaze position was monitored with an infra-red video eye-tracker sampling at 250 Hz. The spatial distribution of fixations was estimated by a locally weighted quadratic regression (loess) with a Gaussian kernel of standard deviation 2.5 deg, although the exact value was unimportant. As display duration was limited, only the first four fixations were analyzed. Within scenes, the first and subsequent fixations, pooled over observers, were found to be only moderately correlated with reported detections (R2 = 55%) but strongly correlated with each other (R2 = 83%), suggesting that observers maintained a constant search strategy for a given scene. This constancy was not an artifact of a central viewing bias, since across scenes fixations were relatively weakly correlated (R2 = 34%). Although top-down effects in visual search may be uncertain, they appear to be less variable than expected.
Acknowledgement: EPSRC EP/F023669/1

33.426 **Contribution of head movements to gaze shift during visual search in a large visual field** Yu Fang[1](fangyork@riec.tohoku.ac.jp), Ryoichi Nakashima[2,3], Kazumichi Matsumiya[2], Rumi Tokunaga[2], Ichiro Kuriki[2], Satoshi Shioiri[2,3]; [1]Graduate School of Information Sciences, Tohoku University, Japan, [2]Research Institute of Electrical Communication, Tohoku University, Japan, [3]Japan Science and Technology Agency, Core Research for Evolutional Science & Technology

[Purpose] A gaze is directed to a point of interest in the visual field. Despite the fact that the shift of gaze is accomplished with combinations of eye, head and body movements, no studies, as far as we know, investigated the gaze control system under free head and body movements. The purpose of this study is to investigate the relationship between the eye and head movements for a natural task in a natural viewing condition: that is, during visual search in a 360°filed display. [Experiment] We measured participants' eye, head and body movements while they were searching a target, T, among distractors, L, presented in a 360° visual display; six LCD displays surrounding the participant. The participant naturally moved his head, eyes, and body to search for the target and then pressed a button when he found the target. We analyzed the amplitude of the eye and head movements for each gaze shift to estimate contributions of the head and eye to gaze shift. [Results] Relative contributions of the head and eye varied with gaze size. When gaze shift amplitude is less than 40°, the contribution of head movements is less than 15% while it when it is over that range, the contribution of head becomes as much as 85%. [Discussion] We found that the contributions of head and eye movements to gaze shift systematically varies with gaze shift amplitude. A study with gaze shifts to a peripheral target reported similar effect of gaze shift size without clear contribution of head movements for small gaze shift. Our finding suggests that similar but not identical control of gaze shift may occur in the daily life as in the case of gaze shift to a peripheral stimulus.

Acknowledgement: CREST

33.427 Searching for many targets: What can eye-movements tell us about hybrid visual and memory search?

Trafton Drew[1,2](traftondrew@gmail.com), Jeremy M. Wolfe[1,2]; [1]Brigham and Women's Hospital, [2]Harvard Medical School

In "Hybrid" Search, observers memorize a number of possible targets and then search for any of these in visual arrays of items. How is Hybrid Search accomplished? 1. Observers might search through the memory set each time a visual item is evaluated. 2. Observers might search the entire visual display for one target at a time, requiring multiple sequential searches. In the current set of experiments, we tracked eye-movements during Hybrid Search for photorealistic objects. Observers searched for one of 1, 4, 16, or 100 targets amongst 8 or 16 possible items. Wolfe (2012) has previously shown that reaction times in Hybrid Search increase with the log of the memory set size. Thus, the increase from 1 to 4 possible targets is roughly equivalent to the increase from 4 to 16 targets. In our data, distractor dwell time also increased in a loglinear fashion with memory set size, providing strong evidence that hybrid search is accomplished through a memory search for each visual item that is fixated. There was no evidence for multiple searches through the display as would be expected if each target was searched for separately. In addition, memory set size had a profound effect on the number of items that were fixated: when searching for one item, only 7% of distractors was fixated, while 54% of distractors was fixated with a memory set size of 100. It is possible that fewer items were fixated at smaller memory set size because a more precise template could be used to reject many visual items. Alternatively, Os may have processed many items in a single fixation when the memory set was small; either by multiple, serial deployments of covert attention or by expanding function visual field, allowing for processing of multiple visual objects in parallel (Young & Hulleman, 2012).

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33.428 Template-based guidance in visual search is independent of influence from properties of currently or recently fixated objects

Valerie Beck[1](valerie-beck@uiowa.edu), Andrew Hollingworth[1]; [1]Department of Psychology, University of Iowa

Observers can use an attentional template consisting of a task-relevant feature (target template) to efficiently guide eyes to matching objects in an array. One explanation for this behavior is that perceptual processing of the currently fixated object biases observers to fixate objects with similar features. Another possible explanation is that observers continue to strengthen this target template by fixating objects that have the relevant feature. In real-world search tasks, however, observers frequently fixate objects that do not have task-relevant features. How do these task-irrelevant saccade targets influence the integrity of the target template and efficiency of search? To test this, observers performed a gaze-contingent search task (find the circle with a top or bottom gap) and we examined how the history of fixating objects with one feature value (e.g., blue) influenced selection of the next object when presented with a choice. Red and blue circles appeared one at a time, and each required fixation before the next would appear. At varying points during a trial, two circles (one blue, one red) appeared equidistantly from the currently fixated circle (choice point). When observers did not know the color of the target item (no target template), they fixated a circle that matched or did not match the choice point color equally often and independently of the number of blue or red circles fixated sequentially before the choice point. When observers did know the target item color (active target template), they consistently fixated the task-relevant circle, regardless of how many task-relevant or irrelevant circles were recently fixated. These results suggest that the target template representation is buffered from both the potential effects of perceptual priming and interference generated by incidental encoding of fixated objects into visual working memory. Guidance appears to be independent of the incidental perceptual events occurring during visual search.

33.429 Optimal search by initially looking away from the target in the presence of remote cues

Stephen C. Mack[1](mack@psych.ucsb.edu), Emre Akbas[1], Miguel P. Eckstein[1]; [1]University of California, Santa Barbara

During visual search, humans often direct their eyes towards image regions which resemble the target (Rao et al., 2002; Zelinsky, 2008) or toward objects which often spatially co-occur with search targets (Eckstein et al., 2006; Torralba et al., 2006). This behavior is consistent with a saccadic targeting (maximum a posteriori) model, which often approximates the ideal searcher. Here, we report a scenario in which an ideal searcher and humans initially look away from the target in the presence of remote spatial cues to optimize performance. Method: Observers performed a free eye movement search task in which they were to indicate the presence of a Gabor (12 cycles/º) embedded in white luminance noise. The target appeared at one of ten locations arranged in two semi-circles. The orientation of three remote spatial cues (large C's), situated between the two groups of target locations (eccentricity 5º), indicated where the target would appear if it were present. Observers performed task variants in which the cues differed in whether they provided target location information (C's vs. O's), how visible the information in the cues was (large vs. small gap), or whether the cues could be foveated. Results: Performance when remote cues were predictive (95.1±.3%) vastly exceeded that of when the cues did not predict location (60.9±.2%). Moreover, observers systematically directed early saccades towards the cues when they provided target location information. When cues were non-predictive, they were largely ignored and a sequence of eye movements which surveyed as many target locations as possible prevailed. Critically, when cues were predictive but observers were prevented from foveating them, performance suffered (62.5±.5%) compared to when saccades were unrestricted. Conclusions: Humans display initial eye movement patterns which depart from a well-established saccadic targeting strategy when these atypical saccades can enhance performance, as is the case with remote spatial cues.

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Binocular vision: Rivalry

Sunday, May 12, 8:30 am - 12:30 pm

Poster Session, Orchid Ballroom

33.430 Winner-take-all circuits exhibit key hallmarks of binocular rivalry

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Perception is inherently ambiguous. Binocular and perceptual rivalry model such ambiguity by presenting constant stimuli that evoke alternating perceptual interpretations. We modeled key phenomena that are common to nearly all forms of rivalry: i) Dominance durations, the times in which a single percept is perceived, follow a heavy-tailed distribution. ii) Changes in stimulus strength (e.g., contrast of one or both stimuli) have well defined effects on dominance durations (Levelt's propositions). iii) Sufficiently long periodic stimulus removal ("blanking") stabilizes the percept, while short blanking destabilizes it. Our model consisted of three coupled winner-take-all (WTA) circuits. Each WTA circuit contained two excitatory units that projected to one inhibitory unit, which in turn projected to both excitatory units. To test the model's quantitative predictions, we performed two binocular rivalry experiments for obtaining fine-grained measurements about the relation between stimulus strength and dominance durations. Small (0.6° visual angle) sinusoidal gratings (oriented +45° in one eye, -45° in the other) were used at 6 contrast levels per eye (36 in total). Contrast levels were adjusted individually. In experiment 1, stimuli were continuously presented (blank duration 0); in experiment 2 the number of contrast levels

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was reduced to 3, but blank duration and inter-blank presentation duration were varied. We found that the network exhibited all three aforementioned hallmarks of rivalry. Furthermore, the model made novel predictions on the functional dependence of dominance durations on stimulus strength, blank duration and inter-blank duration, which were well compatible with experimental data. Beyond predicting all hallmarks of rivalry, our model is well founded in neuronal circuitry. It is a generic model of competitive processes rather than tailored to explain specific aspects of rivalry. Hence our model provides a natural link from rivalry to other forms of perceptual ambiguity and to other competitive processes, such as attention and decision-making.

Acknowledgement: German Research Foundation (DFG) grant EI 852/3

33.431 **Constraining the dynamics of multi-stable perception** Jochen Braun[1](jochen.braun@nat.uni-magdeburg.de), Gustavo Deco[2], Alexander Pastukhov[1]; [1]Cognitive Biology, University of Magdeburg, Germany, [2]Theoretical Neuroscience, University Pompeu Fabra, Barcelona, Spain

The dynamics of multi-stable perception is known to reflect several stabilizing and destabilizing factors. This interplay is captured by simplistic computational models (e.g., Laing & Chow, 2002, J. Comp. Neurosci., 'LC-model') with mutual inhibition, adaptation, and noise, at least under restrictive stimulus conditions. Hoping to constrain the parameters of such models, we collected reversal statistics from 24 observers and with 3 multi-stable displays (binocular rivalry, structure-from-motion, and Necker cube). We compared these observations to reversal sequences generated by a reduced LC-model in a 5-dimensional parameter space. As expected, the distribution of dominance periods exhibited a highly consistent shape (Gamma-like with $\alpha=3.6\pm0.5$), which has been proposed as an effective constraint for multi-stable dynamics (Shpiro et al., 2009, J. Comp. Neurosci.). However, we found that approximately 66% of the possible parameter volume generated realistic distribution shapes with suitable levels of noise. Thus, distribution shape is not, by itself, an effective constraint. Also as expected, reversal sequences exhibited weak (up to c=0.4) but significant correlations between dominance episodes and an integral measure of prior perceptual history (`cumulative history', Pastukhov & Braun, 2011, J. Vis.). In addition, serial correlations (up to c=0.2) between successive dominance episodes also reached significance occasionally (Van Ee, 2009, J. Opt. Soc. Am. A). We found that both observations are consistent with and, indeed, predicted by, the LC-model with suitable levels of adaptation. When combined, dominance distribution and history-dependence constrained multi-stable dynamics effectively. Approximately 15% of the possible parameter volume of the LC-model generated reversal sequences with realistic statistics in both regards. Between 3% and 6% of the parameter volume reproduced the perceptual dynamics of individual observer/display combinations. We conclude that the combination of dominance distribution and history dependence constrains the perceptual dynamics of individual human observers, revealing the operative balance of mutual inhibition, adaptation, and noise.

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33.432 **A Common Mechanism for Perceptual Reversals in Motion-induced Blindness, the Troxler Effect, and Perceptual Filling-In** Dina Devyatko[1](tsukit86@gmail.com), L. Gregory Appelbaum[2], Stephen R. Mitroff[3]; [1]Cognitive Research Laboratory, National Research University Higher School of Economics, [2]Department of Psychiatry, Center for Cognitive Neuroscience, Duke University, [3]Department of Psychology & Neuroscience, Center for Cognitive Neuroscience, Duke University

Several perceptual phenomena strikingly demonstrate that visible stimuli can fluctuate into and out of awareness; a physically available object will alternate between being perceived and being 'invisible' due to motion-induced blindness (MIB; Bonneh, Cooperman and Sagi 2001), the Troxler effect (TE; Troxler, 1804), and perceptual filling-in (PFI; Ramachandran and Gregory, 1991). There are clear differences between these three paradigms, but each produces a similar phenomenology. A common underlying mechanism responsible for the illusory disappearances has been proposed between MIB and PFI (Hsu, Yeh, Kramer, 2004) and PFI and TE (Komatsu, 2006; De Weerd, Smith and Greenberg, 2006), but it remains unknown how they all relate to one another. In the current study, participants (N=69) completed MIB, TE, and PFI paradigms — MIB: a yellow dot was imposed on a rotating grid of blue crosses; TE: a green dot was presented against a static gray background; PFI: a gray dot was presented against background noise. Two measures were calculated for each participant for each paradigm: the number of dot disappearances and the accumulated duration of the disappearances. To control for alterative explanations, eye movements were monitored and thresholds for the detection of motion coherence and changes in motion speed were determined for each participant. Significant correlations were found between the three paradigms for the number (r's>0.48, p's>0.001) and duration (r's>0.34, p's>0.01) of dot disappearances, and none of the effects were driven by eye movements or differences in motion coherence or speed perception thresholds. Principal component analyses conducted for the number and duration of disappearances revealed a single factor which explained a large proportion of the variance in MIB, TE, and PFI; 67% for the number and 60% for duration of disappearances. The results suggest a single oscillatory mechanism may underlie these diverse perceptual phenomena.

33.433 **A Neural Network for Modulation of Perceptual Rivalry by Social Face Traits** Spas Getov[1](s.getov@ucl.ac.uk), Bahador Bahrami[1,2,3], Joel Winston[1,2], Geraint Rees[1,2]; [1]Wellcome Trust Centre for Neuroimaging, Institute of Neurology, University College London, United Kingdom, [2]UCL Institute of Cognitive Neuroscience, University College London, United Kingdom, [3]Interacting Minds Project, Institute of Anthropology, Archaeology and Linguistics, Aarhus University, & Centre of Functionally Integrative Neuroscience, Aarhus University, Aarhus, Denmark

Access to visual awareness is modulated by markers of social relevance, including facial expression, gaze direction, and social face traits such as dominance. The neuronal mechanisms mediating this modulation remain incompletely understood. During binocular rivalry, observers' perceptual experience alternates between two different monocular images. This allowed us to measure how markers of social relevance affected visual competition during rivalry. We hypothesised that dominant faces would be associated with slowed switch rates, and this modulatory effect would correlate with BOLD signal changes in inferior frontal gyrus (IFG). Stimuli comprised monocularly presented faces (measuring 0 or +3SD along a trait dominance dimension; Oosterhof & Todorov, 2008), and Gabor patches presented to the other eye. In a behavioural experiment, 69 participants reported their perception by holding one of three buttons to indicate perception of a face, grating, or mixture. In a second imaging experiment, 19 of these individuals performed the same behavioural paradigm while undergoing BOLD contrast fMRI using a 3T Siemens Trio. Each rivalry period was matched with a 'replay' period: non-rivalrous stimuli reproduced the sequence of percepts through binocular stimulation and transitions yoked to the preceding rivalry period. In the behavioural experiment, binocular rivalry switch rate was significantly slower in socially dominant compared to neutral-face trials. In the neuroimaging experiment, perceptual transitions during binocular rivalry engaged a fronto-parietal network, including right insula and superior parietal lobule. Perception of dominant faces was associated with activity in fusiform face area bilaterally, left superior temporal sulcus (STS) and left IFG. The interaction between main effects of rivalry and face dominance, highlighting regions differentially responsive during rivalry/replay depending on social dominance, was reflected in activation bilaterally in IFG, STS, and amygdala, and hypothalamus. These results demonstrate that socially relevant facial cues modulate access to visual awareness and provide new insight into the underlying neural mechanisms.

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33.434 **Visual and haptic priming of binocular rivalry** Erich W Graf[1](erich@soton.ac.uk), Kieran Rones[1], Daniel H Baker[2], Wendy J Adams[1]; [1]Psychology, University of Southampton, UK, [2]Psychology, University of York, UK

Binocular rivalry describes the perceptual alternations that occur over time when dissimilar images are presented to the two eyes. Many factors affect dominance in rivalry, including low-level image attributes such as contrast or broadband spatiotemporal structure. Rivalry dominance can also be influenced by factors external to the stimuli, such as attention and spatial context. Recent work has found that unambiguous primes can facilitate or suppress a congruent rivalry image, depending on the prime strength, e.g. amount of luminance contrast (Pearson and Brascamp, 2008). We investigated the potential crossmodal aspects of rivalry priming. The present study asks whether similar facilitatory and suppressive effects can be seen for crossmodal primes. Each block of trials consisted of 120 3s Prime-Blank-Rivalry sequences. Rivalry stimuli were oriented Gabor patches (±45° from vertical), one to each eye. The prime stimulus matched one of the two rivalry patches. Primes were presented either visually (same image to both eyes), haptically (using a Phantom force feedback device), or in both visual and haptic domains simultaneously. Additionally, prime strength was manipulated by varying contrast (visual primes) or ridge height (haptic primes). The effect of the prime on onset dominance was modulated by prime strength (higher luminance / ridge height values). At low strengths, the prime stimulus facilitated the perception of the congruent rivalry stimulus. Conversely, at higher strengths, the prime supressed the congruent rivalry stimulus. In addition, the visual/haptic prime data showed evidence of a cross-modal additivity; both the visual and haptic components contributed to increase the effective strength of the prime.

33.435 Shape binds to surface, surface not to shape

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The brain is thought to process different stimulus properties in parallel. The separately processed properties have to be bound together in order for us to experience and react to unified percepts. Here, I performed an experimental manipulation of the percept durations of surfaces, and examined the effects on percept durations of corresponding shape percepts. I did this by combining binocular rivalry with the bistable perception of the Necker cube. I overlaid orthogonal diagonal plaids on the front and back planes of the Necker cube, and presented only one of these plaids to each eye. This ensured binocular rivalry in the middle square of the Necker cube. The Necker cube was presented to both eyes. I examined the effect of increasing plaid contrast – which is known to decrease percept durations for the rivaling plaid in the other eye – on percept durations of the corresponding Necker cube percepts (where the surface partially occluded through rivalry is in the back). I predicted that the Necker cube percepts would at least to some extent follow the perceived plaid percepts. Results confirmed my prediction. Surprisingly, the effects of enhanced plaid contrast on Necker cube percept durations were even stronger than those on plaid percept durations. In a control condition where plaid contrast was also enhanced, but both plaids were presented to both eyes, I found effects that resembled those obtained in the rivalrous case. In an additional manipulation of the Necker cube percept durations –by introducing converging Necker cube diagonals, clearly favouring one of both depth percepts– we found no evidence for the opposite effect, of surface-to-shape binding. We conclude that the higher contrast surface is interpreted as nearer, irrespective of whether the other plaid is suppressed and occluded or not. These findings indicate that shape binds to surface, and surface not to shape.

33.436 Efficient activation of letter-level representation in binocular rivalry with familiar letters

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Binocular rivalry between brief stimuli (onset rivalry) can be modulated by presenting a preceding stimulus. Analyzing the properties of the dominance modulation can provide insights into how different types of stimulus are represented in the visual system. This study investigated dominance modulation using familiar letters (Japanese Kana and Kanji letters) and found that letter-specific negative modulation was predominant. That is, monocularly presenting one of the rivalrous letters prior to dichoptic presentation phenomenally suppressed the same letter regardless of the eye of presentation and thus another letter became dominant in the subsequent onset rivalry. This letter-specific suppressive effect was observed when the duration of the rivalrous test stimulus was either short (30 ms) or long (200 ms). These results are different from those obtained with grating stimuli and color disks. The previous study using these simple stimuli (Abe, Kimura & Goryo, 2011, Journal of Vision, 11(13):6, 1-18) showed that strong eye-based suppressive effects were observed when the test duration was short (10 ms), whereas orientation- or color-based suppressive effects became stronger when the test duration was long (200 ms). Further investigation with letters showed that the letter-specific suppression was unaffected by reducing the size of the preceding letter. However, when a masking pattern was binocularly presented during the ISI between the preceding and rivalrous letters and thus letter-form processing of the preceding letter was interfered, the eye-based suppression was observed. These results suggest that letter-level representation, rather than the one associated with low-level local features, can be efficiently and binocularly activated and used to resolve binocular competition between letters. Further investigation with Kana letters showed that this letter-level information is not represented in an orientation-selective fashion; the upright preceding letter phenomenally suppressed the same upright test letter more strongly than the inverted one, and vice versa.

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33.437 What determines the depth of interocular suppression during continuous flash suppression?

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A potent form of interocular suppression, called continuous flash suppression (CFS), occurs when a dynamic, changing pattern (e.g. a series of Mondrians) flashed continuously to one eye renders an image presented to the other eye undetectable throughout the viewing period. Although the spatiotemporal structure of the two stimuli can influence the depth of interocular suppression (Yang & Blake, 2012), the precise nature of the mechanisms that mediate CFS and the conditions under which it occurs have not been well studied. We sought to investigate if CFS depends on the relative contrasts and mean luminances of the suppressing and supressed stimuli. The suppressing stimulus was dynamic (10 Hz) 2D visual noise presented to one eye and the probe stimulus presented to the other eye was a horizontal sinusoidal grating (1.8 c/°) that underwent a smooth temporal contrast increment in either the top or bottom half of the display. Observers (N = 8) judged the probe location and increment thresholds were measured using an adaptive staircase for each of a range of dynamic noise contrasts (0 to 0.8), grating pedestal contrasts (0 to 0.4) and interocular differences in mean luminance (ratio 1 to 0.06). Results showed that the depth of interocular suppression due to CFS increased strongly (by up to a factor of ~ 25) with the contrast of the dynamic noise. The threshold versus noise contrast function was characterised by a straight line on linear-log axes. The slope of this line (an index of suppression gain) differed markedly between observers but was affected little by the pedestal contrast of the grating. Systematically reducing the mean luminance of the dynamic noise relative to the grating progressively reduced the measured suppression. Thus CFS is not an all-or-nothing phenomenon and its potency depends critically both on low-level stimulus properties (e.g. contrast and luminance) and the individual observer.

33.438 Exploring the phenomenology of a visual change in VWM change detection: A comparison of a perceived change triggered by a VWM-perception mismatch versus a binocular sensory mismatch

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A visual change in VWM-based change detection was reported to resemble a salient pop-out in visual search (Hyun et al, 2009). To explore the nature of such efficient detection of a visual change, we compared the detection of a VWM-perception mismatch against a sensory mismatch driven by two concurrent binocular inputs. In the present study, participants wore a pair of shutter-glass goggles and viewed two identical sets of colored boxes (setsize 2, 4, 6) displayed respectively to each individual eye. The binocular sets of boxes were perceived as a single coherent array of colored boxes, and their colors were asked to be remembered. The memory array was then followed by a test array consisting of another set of binocularly-displayed colored boxes. In half of trials, the test array was exactly the same as the memory array (i.e., change-absent trials) whereas potentially evoked two types of a change in the remaining half (i.e., change-present trials): Half of change-present trials had an identical color change across corresponding boxes in both binocular test items (i.e., both-change trials) while the remaining half had a color change in either of the binocular test items (i.e., either-change trials). The results showed the proportion of "change" responses in both- and either-change conditions was fairly large and comparable to each other when the setsize was 2 and 4. However, when the setsize was 6, the proportion in both-change condition decreased substantially compared to either-change condition, leading to an apparent lack of sensitivity to the change only in both-change condition. These results indicate a VWM-perception mismatch can pop-out as strongly as a binocular sensory mismatch unless VWM-capacity is challenged, and further suggest the phenomenological experience of detecting a supra-threshold visual change presumably resembles the sensation of automatic detection of a sensory conflict across two simultaneous perceptual inputs.

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33.439 Perceptual suppression during stimulus rivalry diminishes contrast adaptation at eye-specific processing stages

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Stimulus rivalry is a variant of binocular rivalry where the two competing images are rapidly and repeatedly swapped between the eyes. Perceptual dominance periods of a given image can extend across many eye swaps during stimulus rivalry, which has led to the view that stimulus rivalry relies on eye-independent neural processes, consistent with a neural origin beyond early visual cortex. In our first experiment we measured the threshold elevation aftereffect (TEAE) following adaptation to an image engaged in stimulus rivalry, and compared this to a situation where the adapter was not rivaling. We observed reduced TEAEs following stimulus rivalry, indicating diminished contrast adaptation during stimulus-rivalry suppression. This result suggests that stimulus rivalry arises in part in or before early visual cortex, the putative locus of the TEAE. Contrast adaptation is partly eye specific, and in a second experiment we investigated this eye-specific component during stimulus rivalry. During stimulus rivalry each image is alternately projected into the left eye and into the right eye, and we found that suppression of an images at a given moment specifically diminished adaptation associated with the eye viewing the image at that moment. Considered together, these results suggest that the neural events at the basis of stimulus rivalry include events at eye-specific stages at or before early visual cortex. We have developed a computational model of stimulus rivalry that successfully implements this idea.

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33.440 **Use of dichoptic random dot kinematograms to assess amblyopic suppression** Cristina Llerena Law[1](cllerenaod@gmail.com), Benjamin Backus[1], Alexander Yuan[1], Oksana Natanelova[1], Lisa Steele[1], Ivan Tseng[1], Lanya Cai[1]; [1]SUNY State College of Optometry

Binocular mechanisms affect monocular visual function in amblyopia. Human and animal amblyopes show evidence of intact binocular mechanisms, but interocular suppression is chronic. Measuring suppression is therefore important for understanding amblyopia and for designing binocular stimuli for treating amblyopes (e.g. Hess et al, Optom Vis Sci, 2010; Li et al, IOVS, 2011). A measure of suppression is interocular contrast ratio (ICR), which estimates the relative signal strengths of the two eyes after combination. Following Hess, Thompson, and colleagues we used dichoptic random-dot kinematograms with signal dots in one eye and noise dots in the other. Amblyopes reported dot direction on each trial and interocular contrast ratio was under the control of a staircase procedure. We tested the robustness of this measure to changes in stimulus size and percent coherence within displays. Fourteen amblyopes and 8 control subjects ran in one to four sessions. Stimuli lasted 300 ms and contained 100 moving dots, presented using either a mirror stereoscope or a rear projection screen and stereo shutter glasses. ICR was highly robust to changes in percent coherence between 18 and 36 percent, and to stimulus size between 5 and 10 deg diameter. Suppression as measured by ICR was maximum in central vision and fell with eccentricity. Thus, use of this method to measure binocular suppression in amblyopes is robust to changes in stimulus size (and thus viewing distance from a display) and to changes in percent coherence (and thus individual differences in percent coherence threshold), increasing its relevance for use as a clinical tool. Across subjects it correlated with a binocular pattern contrast adjustment task (Ding and Sperling, Proc Natl Acad Sci, 2006). It may therefore be convenient to use for binocular approaches to the treatment of adult amblyopia.

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33.441 **Alcohol promotes piecemeal percept during binocular rivalry** Para Kang[1](para@uic.edu), Xiaohua Zhuang[1], Sang Wook Hong[2], Andrea King[3], Dingcai Cao[1]; [1]Dept. of Ophthalmology & Visual Sciences, University of Illinois at Chicago, [2]Dept. of Psychology, Florida Atlantic University, [3]Dept. of Psychiatry & Behavioral Neuroscience, University of Chicago

It has been shown that the rate of perceptual alternation between the left- and right-eye images during binocular rivalry is slowed by alcohol intake (Donnelly & Miller, 1995), indicating that alcohol enhances inhibitory mechanism that mediates visual competition. In previous studies, the acute alcohol effects on binocular rivalry have only been studied with simple geometric stimuli. These stimuli make it difficult to determine whether the alcohol influence on rivalry dynamics can occur at the object representation level. The purpose of this study is first to test the effect of alcohol on simple (two orthogonal 4cpd sinusoidal gratings) and complex stimuli ("face" and "house" images). In addition, the orthogonal sinusoidal gratings composed of either low (2 cpd) or high (6 cpd) spatial frequencies were used to investigate whether the inhibitory alcohol effect is spatial frequency specific. Young participants (N = 13, age 25±2.5 yrs) were tested in two randomized sessions, placebo and alcohol (0.8g/kg), and during each session they were tested twice, before the beverage and after the beverage consumption. The stimulus testing order was randomly interleaved. Participants reported rivalry percepts as a left-eye image, right-eye image or a piecemeal (mixed percept) by pressing pre-assigned buttons. The results showed that alcohol slowed alternation rate (approximately from 21 alternations to 15 alternations per minute) while alcohol's reduction in alternation rate did not differ among stimulus types. Moreover, alcohol selectively increased the mean dominance time of piecemeal percepts from ~3.5 sec to ~5.5 sec after alcohol intake. However, the mean dominance time of the left or right eye image did not increase greatly (~0.4 sec increase) by alcohol. These results suggest that alcohol may interfere with the process for perceptual organization, leading to an increase in the likelihood of asynchronized local visual competition.

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33.442 **Age-related effects of size and contrast on binocular rivalry** Amanda M. Beers[1](beersam@mcmaster.ca), Patrick J. Bennett[1], Allison B. Sekuler[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University

Little currently is known about how binocular rivalry changes with aging. However, by studying factors with well-known effects on binocular rivalry, such as contrast and size, a foundation for future studies of aging can be established. The current study measured binocular rivalry in young adults (aged 20-29), junior-seniors (aged 61-69), and senior-seniors (aged 71-78). Stimuli were pairs of orthogonal oblique sine wave gratings presented dichoptically. Stimuli size (diameter = 2.4o or 4.3o) and contrast level (0.2 or 0.8) varied across trials. On each trial, participants tracked alternations among four percepts (i.e., the two exclusive percepts, mixed, and other). Participants were instructed to report the "other" percept if they perceived fading of the stimuli or any percept that did not match the given response options. Dependent measures were the average duration and proportion of time subjects reported viewing each percept. The average durations for both exclusive percepts were longer in older adults, supporting previous findings (Jalavisto, 1964, Gerontologia, 9, 1–8; Ukai et al., 2003, Percept. Mot. Skills, 97, 393–397). Additionally, the strength of monocular dominance increased with age, particularly when viewing our smaller stimuli, and the proportion of mixed percepts decreased with age. Across all participants there was a marginally significant increase in the proportion of mixed percepts for our larger stimuli, consistent with previous results obtained with younger participants (Blake et al., 1992, Vis. Neurosci., 8, 469–478). In the low contrast condition, senior-seniors reported a statistically higher proportion of other percepts, presumably representing a greater amount of stimulus fading. Overall the senior-seniors were the most statistically different. The sequential pattern of alternations between percepts also varied across age groups. Control experiments indicate that these results were not due to age differences in motor response time or retinal illuminance. The theoretical implications of these results will be discussed.

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33.443 **Neuronal correlates of binocular rivalry in the human medial temporal lobe** Hagar Gelbard-Sagiv[1](hagar@caltech.edu), Liad Mudrik[1], Christof Koch[1,2], Itzhak Fried[3,4]; [1]Division of Biology, California Institute of Technology, [2]Allen Institute for Brain Science, Seattle, [3]Department of Neurosurgery, David Geffen School of Medicine and Semel Institute For Neuroscience and Human Behavior, University of California, [4]Functional Neurosurgery Unit, Tel-Aviv Medical Center and Sackler School of Medicine, Tel-Aviv University, Israel

Firing of neurons in the human medial temporal lobe (MTL) was shown to correlate with conscious perception both using flash suppression (Kreiman et al 2002) and backward masking (Quiroga et al 2008). However, in both of these paradigms, perception was externally manipulated rather than internally driven. Thus, it remains unclear whether MTL neurons are involved in internally generating the percept, or only follow it. Here we used binocular rivalry, where perceptual switches are internally driven, in epilepsy patients implanted with depth electrodes (for clinical purpose). Based on a conventional screening paradigm, pairs of images that elicited selective responses were presented binocularly. Patients were asked to report perceptual transitions by pressing and releasing two buttons. These reports were then used to create a replay condition. We found that neurons in the MTL responded up to 1000ms before patients released the button to indicate the initiation of a perceptual switch (i.e. piecemeal period) to the cells' preferred image. This was found both for cells that expressed selectivity by increasing or by decreasing their firing rate in response to their preferred stimulus. Even after accounting for motor reaction time, these neuronal responses are still quite early, especially considering that MTL neuronal response time is typically 300-400ms after stimulus presentation. It appears that neurons in different areas responded with different times relative to the

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behavioral report of the perceptual switch, with the amygdala generating some of the earliest responses. Importantly, the neuronal response was earlier in the rivalry condition as compared to the replay condition. Our results suggest that MTL neurons are not merely reflecting but likely take part in the process leading to conscious perception or to a switch in perception.

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33.444 **Functionally imaging the magno- and parvocellular layers of the human LGN during binocular rivalry** Debra W. Soh, M.A.[1](dsoh@yorku.ca), Keith A. Schneider, Ph.D.[2,3]; [1]Department of Psychology, York University, Toronto, Canada, [2]Centre for Vision Research, York University, [3]Department of Biology, York University

Introduction. Binocular rivalry occurs when conflicting images are presented to the eyes dichoptically. Rather than being perceived as one cohesive image, the two images compete for perceptual dominance, resulting in the images alternating in perceptual awareness. Neural explanations for this phenomenon have been debated; our interest was to determine the involvement of the magnocellular (M) and parvocellular (P) processing streams in rivalry. The lateral geniculate nucleus (LGN) is involved in dominance and suppression of visual input, consists of two ventral M layers and four dorsal P layers, and is the only place in the brain where these streams are spatially disjoint. Previous research has shown that activity in the LGN layers innervated by the suppressed eye is also suppressed during rivalry, but it is not clear whether both M and P streams are equally involved. Methods. Participants were scanned using a Siemens 3T MRI scanner. Functional EPI data were registered to a mean series of high-resolution proton density weighted images on which it is possible to measure the boundaries of the LGN and thus localize the M and P layers. Stimuli were presented through an Avotec binocular goggle system that allowed independent stimulation of each eye. The rivalrous stimuli were two rotating (1 Hz period) discs of high-contrast sinusoidal gratings that varied with regards to colour (red vs. green) and direction of rotation. Subjects held down a button to indicate which of the two stimuli was currently being perceived. Event-related averages were calculated from the functional data within the LGN. Results. The activation strengths of the M and P streams were compared. Both streams were found to participate equally in rivalry. Discussion. These results have implications for potential treatments for clinical disorders that result from M-cell deficits (e.g., dyslexia) and attentional disorders (e.g., attention deficit hyperactivity disorder, neglect syndromes).

Binocular vision: Neural mechanisms and models

Sunday, May 12, 8:30 am - 12:30 pm

Poster Session, Orchid Ballroom

33.445 **Measurement of interocular suppression across the binocular visual field using luminance-modulated and contrast-modulated noise stimuli** Akash S Chima[1](akash.chima@anglia.ac.uk), Sarah J Waugh[1], Monika A Formankiewicz[1]; [1]Anglia Vision Research, Department of Vision and Hearing Sciences, Anglia Ruskin University, Cambridge, U.K.

Suppression is a binocular condition that elicits repression of the visual field evoked by dissimilar inputs received by each eye, such as in amblyopia or when large interocular blur differences exist in normal vision. Contrast-modulated (CM) stimuli may be processed in more binocular areas than luminance-modulated (LM) stimuli (Wong, Levi & McGraw, 2001), and so interocular suppression may be heightened for CM rather than LM stimuli. Extent and depth of suppression was measured using a 24 deg circular stimulus split into rings and sectors. Each ring's area was doubled from the central ring. Observers dichoptically matched the perceived modulation of a moveable sector to that of the surrounding ring, in order to measure the depth of suppression, for different levels of interocular dioptric blur (0-4D). Stimuli were presented on two head-mounted displays. Stimulus noise amplitude was also varied and depth of suppression measured. Increasing interocular blur revealed no local suppression scotomata within the binocular visual field, although a general increase in depth of suppression occurred at significantly different rates of 19% per dioptre with CM, compared to 8% with LM ($p<0.05$), stimuli. Increasing noise amplitude lessened the measured depth of suppression for LM stimuli, but enhanced the depth of suppression for CM stimuli. The depth of suppression increases across the visual field as interocular blur increases, and sensitivity to interocular differences in blur (possibly due to binocular disruption) for CM stimuli is greater. By varying noise strength, the measured suppression depth can be modified. In combination, these findings could be valuable in bringing observers with dense suppression into a measureable range, where more subtle changes in suppression depth could then be monitored.

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33.446 **Binocular contrast discrimination needs monocular multiplicative noise** Jian Ding[1](jian.ding@berkeley.edu), Stanley Klein[1], Dennis Levi[1]; [1]School of Optometry, University of California, Berkeley

We report the surprising result that although binocular vs monocular viewing of a sinusoidal grating has approximately the same perceived contrast, contrast discrimination is $\sqrt{2}$ better for binocular viewing. We argue that the most plausible class of models with this property has a gain control stage with ocular crosstalk whereby the effective contrast of each eye is halved (see Ding and Sperling, 2006), followed by multiplicative noise, and then the summation of the two eyes' signals and noise going to the decision stage. To pin down the model, we performed three experiments using identical stimuli to measure perceived phase, perceived contrast, and contrast discrimination of a cyclopean sinewave. On each trial, horizontal sinewaves (0.68 cpd) were presented independently to the two eyes using a mirror stereoscope. Perceived phase was measured using a paradigm adapted from Ding and Sperling (2006). (The perceived phase is sensitive to the ratio of right and left eye contrasts and is important for pinning down the gain control parameters.) Perceived contrast was measured by matching the contrast of a binocular grating to a monocular standard. Contrast discrimination was measured with both pedestal and test sinewaves either in the same eye (monocular), in different eyes (dichoptic), or in both eyes (binocular). A modified Ding-Sperling model (Ding, Klein and Levi, in press) plus a contrast discrimination mechanism were used to fit all three data sets simultaneously. We tested four different model configurations: multiplicative noise or a non-linear contrast transducer could be either inserted before or after the combination site. Only multiplicative noise inserted before the combination site was able to account for the data.

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33.447 **Dynamic properties in broadband pattern masking: Comparison between monocular, binocular and dichoptic viewing conditions.** Pi-Chun Huang[1](pichun_huang@mail.ncku.edu.tw), Robert Hess[2]; [1]Department of Psychology, National Cheng Kung University, Tainan, Taiwan, [2]McGill Vision Research, Department of Ophthalmology, McGill University, Montreal, Canada

To assess how remote spatial frequency components of the mask influence the pattern masking in temporal domain, the masking effect was measured under various presentation duration (50, 100, 250 and 1000ms) in monocular, binocular and dichoptic viewing conditions. The target was a horizontal sine-wave grating with spatial frequency of 1 cpd. Three types of masks with the same fundamental spatial frequency were used: a sine-wave grating(S), a square-wave grating (Q), and a missing fundamental square-wave grating (M). The contrast of the mask was set at either 0% or 40%. A spatial four-alternative-force-choice was used to measure the target threshold. The results showed the presentation duration had no main masking effect, suggesting the masking occurs fast, at least within 50ms. Under monocular and binocular viewing conditions, the Q mask caused a stronger masking effect than the S masks and the M masks also caused significant masking. Under dichoptic viewing, on the contrary, the S masks caused stronger masking than the Q masks and masking effect also occurred in dichoptic M mask. These results suggested that the contributions of remote spatial frequencies are rapid, occurring within 50ms and differ under monocular and dichoptic viewing.

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33.448 **Evidences of bidirectional eye suppression in amblyopia** Dave Saint-Amour[1, 2](saint-amour.dave@uqam.ca), Laura Lefebvre[2, 3], Mathieu Simard[2], Reza Farivar[4], Robert F. Hess[4]; [1]Department of Psychology, University of Quebec in Montreal, [2]Research Center, CHU Sainte-Justine, [3]Department of Psychology, University of Montreal, [4]McGill Vision Research Center, McGill University

A growing body of evidence suggests that binocular interactions are still present in amblyopes under certain viewing conditions, even in adults. Here we determined whether suppression was bidirectional (from dominant eye to the amblyopic eye but also from the amblyopic to the dominant eye) and explored the neural correlates. We tested the degree of suppression in 8 strabismic adults and 8 controls by using a flash suppression paradigm: a 30%-contrast grating was presented to one eye (S1) followed by a flash of another grating presented to the other eye (S2). The magnitude of suppression was manipulated by changing the contrast of S2 (10, 30, 100%).

Sunday AM

For each trial, S1 was presented either at 85 or 95° and S2 at the other orientation while the observers indicated the perceived stimulus throughout the trial. High-density electrical mapping was simultaneously recorded. To specifically measure the cortical response of the suppressed stimulus under dichoptic viewing, S1 flickered at 7.5 Hz to evoke steady-state activity. As expected, the flash suppression effect was found in both groups when S1 was applied to amblyopic (or non-dominant in controls) and S2 to the dominant eye. Suppression was increased with S2 at 100% of contrast and negligible at 10%. The magnitude of the flash suppression at 30% of contrast was about 60% stronger in amblyopes, suggested a facilitatory effect of chronic suppression. The reverse suppression effect was observed such that the amblyopic eye suppressed the response of the dominant eye. EEG topographies revealed maximal suppressive response over the occipital cortex in both groups with a more occipito-parietal distribution in amblyopes. Source localisation modeling is ongoing to better characterise the underlying generators. Thus there is evidence for a bidirectional interaction between the eyes of amblyopes although the inhibition from the dominant eye is stronger.

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33.449 **Dichoptic Orientation Summation** Oren Yehezkel[1,2](yehez@post.tau.ac.il), Uri Polat[1], Dennis Levi[2]; [1]Faculty of Medicine, Goldschleger Eye Research Inst, Sheba Medical Center, Tel Aviv University, Israel, [2]School of Optometry and Helen Wills Neuroscience Institute, UC Berkeley, Berkeley

Although binocular integration of luminance, contrast and phase has been in the spotlight of the fundamental vision research over the past several decades, the manner in which different orientations in the two eyes are combined has not yet been resolved. Here we used dichoptic stimulation to measure the perceived orientation of a foveal Gabor target. The stimuli were presented with orientations of 80, 85, 90, 95 and 100 deg. in 12 dichoptic combinations with 10, 15 or 20 deg. orientation difference between the two eyes. In each combination, one eye was stimulated with a fixed high contrast (20%), and the fellow eye was presented with a contrast of 15, 10 or 5%, the threshold contrast for binocular detection (5%). The threshold for monocular contrast detection was 8%. Subjects were asked to rate the perceived orientation using 5 options (80, 85, 90, 95 and 100 deg.); 6th option was reserved for the "can't decide" response. Each combination was repeated in 100 trials. Binocular and monocular presentations with 20% contrast served as baseline orientation curve per subject with clear stimulation-driven responses. The results show that even stimulation below the monocular threshold of contrast detection combined with the supra-threshold stimulation of the fellow eye to significantly affect the resulting orientation perception. This effect was quantified as a shift in the perceived orientation, with the magnitude of the effect proportional to the contrast presented in the second eye. Moreover, a differential pattern of binocular summation was observed depending on the difference in the orientations presented to the two eyes. Our results suggest that 1) even subliminal input to one eye significantly modifies the overall orientation perception and that 2) the orientation difference between the two eyes determines the extent of binocular integration.

33.450 **Resolving the individual layers of the human lateral geniculate nucleus using high-resolution structural MRI** Larissa McKetton[1,2](mcketton@yorku.ca), Joseph Viviano[1,2], Keith Schneider[1,2]; [1]Department of Biology, York University, [2]Centre for Vision Research, York University

Introduction: A large number of visual sensory pathways relay through the lateral geniculate nucleus (LGN), a visual relay and control nucleus in the thalamus that normally is organized into six interleaved monocular layers. Neuroimaging studies have not been able to reliably distinguish these layers due its small size— total maximal diameter of 4–6 mm and layer thicknesses of approximately 1 mm. It is a technical challenge optimizing the imaging parameters to provide a sufficient signal to noise ratio (SNR) and tissue contrast to be able to measure these layers in the least amount of time. We used a proton density pulse sequence and varied the acquisition resolution and other parameters to determine the number of images needed to be acquired and averaged to be able to reliably identify the LGN and measure its laminar structure. Methods: Subjects were scanned using a Siemens Trio 3T MRI scanner and 32-channel head coil in York University's Neuroimaging Laboratory. We compared images obtained from variety of scanning parameters and resolutions in terms of their intrinsic SNR as well as their utility in observing structure in the LGN. 40 high resolution proton density (PD) images from one session with a 256 matrix, 48 1 mm thick slices, 0.75x075x1 mm3; 100 PD images from two sessions with a 320 matrix, 15 1mm thick slices, 0.5x05x1 mm3; and 175 PD images from four sessions with a 512 matrix, 30 1mm thick slices, 0.35x0.35x1 mm3. Results The 256 matrix image showed clear demarcation of the LGN borders with slight contrast detection in LGN layers, although not fully distinguishable. At the 320 and 512 matrix acquisitions, the differences between the LGN layers were visible. Conclusions: We have demonstrated that it is possible to differentiate between the eye-specific layers of the LGN using multiple acquisitions of high-resolution structural MRI.

Acknowledgement: NSERC

Perceptual learning: Plasticity, adaptation

Sunday, May 12, 8:30 am - 12:30 pm

Poster Session, Vista Ballroom

33.501 **Visual attention is necessary for the motor-visual temporal recalibration** Masaki Tsujita[1](tsujita@chiba-u.jp), Makoto Ichikawa[2]; [1]Graduate School of Humanities and Social Sciences, Chiba University, [2]Faculty of Letters, Chiba University

Prolonged exposure to fixed temporal lag between observer's keypress and visual feedback recalibrates motor-visual temporal relationship, and consequently shifts the point of subjective simultaneity (PSS) in subsequent temporal order judgments between keypress and visual flash (Stetson et al., 2006, Neuron, 51, 651-659). We conducted two experiments in order to examine how manipulation of observer's attention during adaptation affected the adaptive shift. Experimental sessions were composed of adaptation and test phases. In the adaptation phase, observers constantly pressed a key. Each keypress was accompanied by presenting a white square (1.5 x 1.5 arc deg) for 12 ms as a visual feedback. We injected 0ms or 200ms fixed temporal lag between the keypress and visual feedback. During the adaptation phase, we presented target stimuli with random timing for attentional task in which observers counted the frequency of their presentations. In the test phase, observers conducted temporal order judgment between the keypress and presentation of a square. In Experiment 1, we presented either of a extended fixation cross (from 1.0 x 1.0 arc deg to 3.5 x 3.5 arc deg) or auditory beep (160Hz) as a target for the attentional task. If observers attended to the visual targets during the adaptation phase, the PSS shifted significantly although, if they attended to the auditory targets, we found no significant shift. In Experiment 2, we presented visual targets for the attentional task in the same or opposite visual field in which the visual feedbacks were presented. In this experiment, the PSS shifted significantly regardless of the visual field to which observer attended during the adaptation phase. These results suggest that the motor-sensory temporal recalibration requires attention to the perceptual modality which is engaged in the adaptation.

33.502 **When is old better? Task Irrelevant Perceptual Learning with older people** Li-Hung Chang[1,2](li_hung_chang@brown.edu), Kazuhisa Shibata[1], Yuko Yotsumoto[3], John Andersen[4], Yuka Sasaki[1], Takeo Watanabe[1]; [1]Department of Cognitive, Linguistic, and Psychological Sciences, Brown University, [2]Department of Psychology, Boston University, [3]Department of Life Sciences, The University of Tokyo, [4]Department of Psychology, University of California, Riverside

Visual perceptual learning (VPL) is defined as long-term improvement on a visual task after visual experience. We found that VPL of a task-irrelevant feature (task-irrelevant VPL, or TIVPL) occurs when the feature signal was around the threshold but not when it was suprathreshold (Tsushima et al, 2009). We have suggested that the reason for the differential results is that while the attentional control system detects and inhibit suprathreshold task-irrelevant signals, it fails to detect and thus to inhibit subthreshold signals (Tsushima, Sasaki & Watanabe, 2006). If this is true, TIPL should occur with some suprathreshold irrelevant signals with older people, since older people tend to have weaker inhibitory controls. In order to test this hypothesis, we conducted 8 days of training during which older subjects (n=8, 67-77 yr) were asked to perform RSVP tasks while coherent motion was presented in the background as a task-irrelevant feature. The exposed coherent motion ratio (strength) was varied from trial to trial so that on some trials the presented coherent motion was subthreshold and on other trials it was suprathreshold. A certain motion ratio was always paired with the same coherent motion direction. Before and after the training, we measured performance in the detection of coherent motion directions to examine the magnitudes of TIVPL of subthreshold and suprathreshold motion coherent motion directions. The results indicate that TIVPL with older subjects occurred not only with suprathrshold coherent motion but also with the subthreshold coherent motion with which TIVPL was not observed with younger subjects. These results are in accord with the hypothesis that older people have a smaller degree of inhibitory control than younger people, which allowed TIVPL to occur with suprathrshold task-irrelevant coherent motion.

Acknowledgement: Supported by NIH (R01EY019466, R01AG031941) and Brookline Senior Center

33.503 **The boosting effect of negative feedback on perceptual learning** Hoon Choi[1](Hoon_Choi@brown.edu), Takeo Watanabe[1]; [1]Department of Cognitive, Linguistic & Psychological Sciences, Brown University

In many types of learning including rule-based learning, feedback concerning the accuracy of participant's responses on a given task plays an important role. The effect of feedback depends on its polarity: whether the feedback is positive (indicating the correctness of a response) or negative (indicating the incorrectness). While positive feedback facilitates a temporary internal hypothesis associated with a current response, negative feedback inhibits the hypothesis and leads to development of an alternative hypothesis. To explore whether positive and negative feedback play such differential roles in perceptual learning (PL), we directly compared the effects of positive and negative feedback on PL. Through a 7-day experiment, participants conducted a two-interval-forced-choice grating detection task. In each trial, two displays were presented for 200msec in sequence with a blank interval of 400msec. One display consisted of only spatial white noises (noise interval) while the other display consisted of a dim, rotated grating embedded in a noise background (signal interval). Participants were asked to report which interval included the grating. While no feedback was provided in the pre- or post-test, manipulated feedback was given in every trial during a 5-day training period, with an attempt to dissociate positive and negative feedback. When a grating with a certain orientation (positive orientation) was presented, valid feedback was given. However, if a grating had another orientation (negative orientation), participants obtained reverse-feedback: when they made a correct response (choosing the signal interval), negative feedback was provided, whereas positive feedback was given for a wrong response (choosing the noise interval). After training, performance significantly improved, not only for the positive orientation, but also for the negative orientation. These results suggest that, unlike other types of learning that are formed through facilitation or inhibition depending on the polarity of feedback, PL is merely boosted by feedback, irrespective of its polarity.

Acknowledgement: NIH (R01EY015980, R01EY014966)

33.504 **Modification of spontaneous oscillatory activity in the visual cortex during non-rapid eye movement sleep associated with adaptation process to a first-night sleep environment** Masako Tamaki[1](tamaki@brown.edu), Ji Wong Bang[1], Takeo Watanabe[1], Yuka Sasaki[1]; [1]Department of Cognitive, Linguistic & Psychological Sciences, Brown University

Our visual system is adaptive and plastic in response to stimuli or environment we experience. Although visual adaptation and plasticity have been extensively studied while participants are awake, little is known while participants are asleep. However, it is vital to understand visual adaptation and plasticity throughout wakefulness and sleep, as visual processing during wakefulness and sleep interacts with each other. It has been well documented that the quality of sleep degrades due to exposure to a new sleep environment, known as the first night effect (FNE). FNE is significantly reduced after the first night because of adaptation to the new environment. It has been suggested that slow-wave activity (SWA) is modified in the first night. SWA is commonly investigated in the frontal or central regions of the scalp, and not in the occipital region. Is the visual system involved in the FNE and adaptation process? To address this question, we measured the strength of SWA (1-4 Hz) originated in the visual cortex during sleep and compared the strength of SWA between the first and second experimental sleep using magnetoencephalography (MEG), polysomnography, and a magnetic resonance imaging (MRI). Young and healthy participants (n = 8) underwent 3-4 nightly MEG sessions during sleep, and one MRI session. Wavelet-transformed MEG during the NREM sleep in the first sleep cycle was combined with high-resolution structural MRI to constrain the sources of SWA to the cortical mantle individually. The results showed that the strength of SWA in the visual cortex was reduced in the first night in comparison to the second night. Thus, the visual system is involved in the adaptation process associated with the FNE, through modification of SWA. These results suggest that the visual system does not cease adapting to a new environment and continues to be plastic even during sleep.

Acknowledgement: This research was supported by NIH (NIH R01MH091801, R01EY015980) and NSF (BCS-0964776). This research was carried out in part at the Athinoula A. Martinos Center for Biomedical Imaging at the Massachusetts General Hospital, using resources provided by the Center for Functional Neuroimaging Technologies, P41EB015896, a P41 Regional Resource supported by the National Institute of Biomedical Imaging and Bioengineering (NIBIB), National Institutes of Health. This work also involved the use of instrumentation supported by the NIH Shared Instrumentation Grant Program and High-End Instrumentation Grant Program specifically, grant number S10RR014978.

33.505 **Do video game players resist interference with perceptual learning by training on a new task?** Aaron Berard[1](aaron_berard@brown.edu), Matthew Cain[1], Takeo Watanabe[1], Yuka Sasaki[1]; [1]Brown University

Long-term exposure to certain types of video games can influence a wide range of mental processes, from visual acuity to cognitive control (e.g., Cain, Landau, & Shimamura, 2012, Green & Bavelier, 2003). Video game players have also displayed generalized improvements in perceptual learning (Green, Li, & Bavelier, 2010). We investigated whether perceptual learning advantages in heavy action video gamers, compared to non-players, included resistance to interference caused by changes in stimulus properties. In the classic texture discrimination task (TDT, Karni & Sagi, 1991), participants report the orientation of an array of oblique lines embedded in a field of all vertical or all horizontal lines and demonstrate robust overnight improvement. However, changing the background line orientation midway through TDT training with no interval between the changes interferes with overnight improvements in performance on TDT with both background orientations (Yotsumoto, Chang, Watanabe, & Sasaki, 2009). Interestingly, no interference occurred with a one-hour interval between the changes. These results have suggested that after training is over, it takes some time for the learning to be stabilized and resilient against interference. Here, we examined the effect of daily video game playing on interference of training of TDT with one background orientation on perceptual learning of TDT with a different background orientation. As a result, we found that non-gamers showed no overnight performance improvements, replicating previous results with the interference TDT. In contrast, action video game players demonstrated overnight improvements in performance with both background orientations, suggesting that they are better able to overcome interference in perceptual learning. This resistance to proactive and retroactive interference suggests that video game playing not only enhances the amplitude and speed of perceptual learning but also leads to faster and/or more robust stabilization of perceptual learning.

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33.506 **Detection reveals multiple temporally tuned mechanisms controlling contrast adaptation** Elizabeth Fast[1](fastx055@umn.edu), Yihwa Baek[1], Juraj Mesik[1], Koen Haak[1], Stephen Engel[1]; [1]Department of Psychology, University of Minnesota

Adaptation optimizes vision to a dynamic world, which changes at many timescales, from very transient to semi-permanent. To adapt optimally, the visual system also adjusts at different timescales, with longer-lasting environmental changes producing longer-lasting effects. But how the visual system adapts in this way remains unknown. We examined whether contrast adaptation is controlled by multiple mechanisms, each operating over a different time scale, by testing for spontaneous recovery, a hallmark of multiple controllers first shown in the animal learning literature. We used an objective task, two spatial alternative forced choice detection of a briefly presented (200 msec) Gabor patch (1 cpd). Test trials were alternated with 1.4 sec adapting Gabor presentations, in a "top-up" design. Three adapter contrasts were used: 25% (baseline), 90% (adaptation) and 5% (deadaptation). In each session, subjects (N = 3) first completed six minutes of baseline trials to determine a threshold contrast, where performance was 70% correct, which was used for calculating test contrasts in the remainder of the experiment. Subjects then performed two minutes of trials in the baseline condition, followed by 10 minutes in the adaptation condition, 80 seconds in the deadaptation condition, and a second eight minutes in the baseline condition. Adaptation produced large, reliable decreases in performance from baseline levels. Deadaptation counteracted these effects, as performance quickly increased to return to baseline levels. However, continued testing in the second baseline period revealed a striking second decrease in performance. This second decrease represents spontaneous recovery of the effects of adaptation. Deadaptation likely produced effects in a distinct, shorter-term controller that cancelled effects of initial adaptation in a longer-term mechanism. As the shorter-term effects decayed, the ongoing longer-term effects reemerged. These multiple temporally tuned controllers may allow vision to adapt optimally to environmental effects that arise at different timescales.

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33.507 **Sequence is necessary for multi-stimulus perceptual learning** Lin-Juan Cong[1](conglinjuan@gmail.com), Jun-Yun Zhang[2], Cong Yu[2]; [1]School of Brain and Cognitive Science, Beijing Normal University, Beijing, China, [2]Department of Psychology and Peking-Tsinghua Center for Life Sciences, Peking University, Beijing, China

Sunday AM

Perceptual learning occurs when multiple stimuli are presented in a fixed order, but not in a random order (roving). But learning can escape roving disruption when each roving stimulus is given a letter tag (i.e., A-B-C-D) (Zhang et. al, PLoS Biology, 2008). Since these letters carry both identity and sequence information, here we investigated which information in stimulus tagging really helps learning with stimulus roving. (1) First we replicated the stimulus tagging effect by assigning four roving contrasts (0.2, 0.3, 0.47, and 0.63) each a number tag (i.e., 1-2-3-4). The number tags also contained both identity and sequence information. Significant learning of contrast discrimination was evident (post/pre-training threshold ratio (PPR) = 0.82±0.05, P=0.010) after five sessions of training. (2) When stimulus tags changed to Greek letters (i.e., δ-ω-λ-θ) that had unfamiliar alphabetic sequence for Chinese observers, learning was disabled by stimulus roving (PPR = 0.94±0.04, P=0.089). (3) Jittering inter-trial intervals (ITI) did not affect learning with number tags (PPR = 0.83±0.07, p=0.041), in contrast to previous results that jittering ITI interrupted learning of multiple contrasts in a fixed order. (4) For the same four contrasts that were each assigned an orientation tag (36°-81°-126°-171°) and presented either with roving or with a clockwise order, contrast learning was evident with a stimulus order (PPR = 0.79±0.13, P=0.049), but was absent with roving (PPR = 0.99±0.08, P=0.29). These results indicate that it is the semantic sequence information in letter or number tagging that helps learning with stimulus roving. Stimulus tags, such as orientation and Greek letters (to Chinese) that carry no sequence information, are ineffective. Unlike stimulus order, the semantic sequence is strong enough that it cannot be interrupted by ITI jittering (no rhythm). These and our previous results together demonstrate that sequence is necessary for multi-stimulus learning to occur.

33.508 Hemifield-specific offline learning of coherent motion detection Matthew S. Cain[1](matthew.s.cain@brown.edu), Sumire D. Sato[1], Takeo Watanabe[1], Yuka Sasaki[1]; [1]Brown University Department of Cognitive, Linguistic, & Psychological Sciences

The ability to detect coherent motion embedded in random noise has been long-studied in perceptual learning, and performance has been shown to improve reliably with practice (e.g., Ball & Sekuler, 1987). Many motion coherence training paradigms focus on very long-term learning (e.g., Shibata et al., 2012, trained participants for 10 days), but recent evidence suggests that motion direction discrimination learning may undergo consolidation in the hours immediately after training (Ashley & Pearson, 2012), especially if sleep is involved (McDevitt et al., VSS 2012). One common element of many perceptual learning tasks is offline learning—improvement in performance that occurs after formal training is complete and the observer is no longer engaged in the task. Such offline learning my be generalized, but is often retinotopically specific. Here, we demonstrate visual-hemifield-specific offline learning of motion detection. Observers were trained to detect near-threshold coherent motion in a single, non-cardinal direction in one visual hemifield. Random, white-noise motion was presented in the untrained hemifield and fixation was enforced with a central RSVP letter discrimination task. Observers showed only modest improvements in motion discrimination ability over the course of the first training session. However, in a retest 24 hours after training, they showed marked improvement in detection ability for stimuli in the trained hemifield, but only slight improvement in detecting stimuli in the untrained hemifield. These results suggest that motion coherence learning has an important offline component that may well be sleep-dependent and, similar to classic sleep-dependent learning paradigms like the texture discrimination task, this offline learning may be retinotopically specific.

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33.509 Visual Improvements Through the Perceptual Learning Based Training Program UltimEyesTM Jenni Deveau[1](jennifer.deveau@email.ucr.edu), Gary Lovcik[2], Aaron Seitz[1]; [1]Psychology, UC Riverside, [2]Anaheim Hills Optometric Center

We rely on our vision for many daily tasks such as navigation, reading, and watching television. Therefore visual deficits due to disease/degeneration of the eye, injury, or aging can have a significant negative impact on one's quality of life. Many occupations heavily rely on vision including law enforcement or healthcare providers. Vision is also essential in the world of competitive sports. Enhancement of visual abilities could have substantial lifestyle benefits. Research in the field of perceptual learning has found many perceptual abilities can improve after training, as well as a variety of factors that promote learning. Based on this research we have developed a video-game based visual training program – UltimEyesTM (UE). UE is designed to improve both central and peripheral vision. It trains on a variety of features with the goal of producing general, not specific vision improvements. Twenty-two healthy participants with normal vision (ages 18-55) completed an average of 24, 25 minute training sessions. Participants showed improvements in both foveal and peripheral acuity and contrast sensitivity after training with the UE program, while control subjects did not show improvements. These results indicate the UE program is sufficient to induce visual improvements after training in participants with normal vision. Following these finding, a 5 year old amblyopic patient completed 32 sessions of the UE program. After training, acuity in the amblyopic eye improved from 20/80 to 20/40, and acuity in the non-amblyopic eye improved from 20/63 to 20/32. Binocular acuity changed from 20/63 (indicating no binocular advantage) to 20/20 (a binocular advantage). Post-training stereoacuity reached 50 sec of arc, where no reading was obtained prior to training. Re-testing confirmed these results persist at least 3 months post-training. These results show that UE has significant potential as a visual training therapy in both normally seeing and low-vision individuals.

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33.510 Learning reconfigures surround modulation of orientation discrimination performance Ben S. Webb[1](bsw@psychology.nottingham.ac.uk), Neil W. Roach[1]; [1]Visual Neuroscience Group, University of Nottingham, UK

Both recent visual history and surrounding visual context modulate discriminative accuracy. Their respective effects upon discrimination performance depend similarly upon the angular difference between the inducing (adapting or surround) and test stimulus. We have recently shown that repeatedly practising a fine discrimination task while in an adapted state completely reconfigures the characteristic effects of adaptation. Here we ask whether learning produces similar effects on surround modulation of discrimination performance. We asked a group of human subjects to report whether the orientation of a sinusoidal grating was tilted clockwise or counter-clockwise of vertical. Before and after training, we measured the baseline discrimination threshold and change in this estimate caused by the presence of a vertical annular surround grating (0°) or two surround gratings oriented symmetrically (± 10 to ± 50°) around vertical. During training, the same group of subjects repeatedly practiced (over 8-10 daily training sessions) discriminating the orientation of the central grating while it was surrounded by two gratings that induced the largest threshold elevation before training. We found that practicing orientation discrimination with surround stimuli present produced significant improvements in discriminative accuracy. Like the effects of learning in an adapted state, these large improvements in the trained surround condition had consequences for untrained surround conditions. Surround conditions that prior to learning had little effect induced a significant cost for discriminative accuracy after learning. Our results suggest that the behavioural signatures of surround modulation are flexible, which has implications for the sort of inferences we can make about surround-induced changes to performance.

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33.511 Learning to discriminate crowded orientations Zhenzhi Fan[1,2](zhenzhifan@gmail.com), Fang Fang[1,2,3,4]; [1]Department of Psychology, [2]Key Laboratory of Machine Perception (Ministry of Education), [3]Peking-Tsinghua Center for Life Sciences, [4]IDG/McGovern Institute for Brain Research, Peking University, Beijing 10081, P.R. China

It has been shown that crowding could be alleviated by perceptual training. The underlying mechanism of the phenomenon has yet to be clarified. Here we tackled this issue through investigating the specificity and generalization of perceptual learning of crowded orientation. Experiment 1 consisted of five phases – pre-test, training, mid-test, training and post-test. Subjects were trained to perform an orientation discrimination task with a target grating (radius: 1.5°; spatial frequency: 2 cycles/°; contrast: 1; orientation: 22.5° or -67.5°; eccentricity: 10°). The target was flanked by two other gratings positioned radially, which were identical to the target except that their orientations were randomized. In the tests, subjects' orientation discrimination thresholds were measured with the target and its orthogonal version, which were presented either alone or with the flankers. After practicing about 1700 trials, subjects' performance was improved significantly. Surprisingly, the crowding effect could be completely eliminated – subjects performed equally well when the target was present alone or with the flankers. More importantly, the improvement can completely transfer to the crowded orthogonal grating, but the transfer to the isolated gratings was weak. Subjects were further trained for 7200 trials over six days. Their performance improvement was found to be largely specific to the trained orientation. Experiment 2 further showed that the orientation discrimination training in Experiment 1 could even completely break motion crowding. Experiment 3 demonstrated that training had little effect when the trained and test stimuli were in different quadrants. These findings suggest that perceptual learning of crowding orientation comprises two stages. In the early stage, subjects acquired a relatively general ability to separate the target and the flankers. In the late stage, they learn to process the target information more accurately and more specifically.

33.512 Perceptual learning of direction discrimination reduces bilateral motion repulsion

Ke Jia[1](jiake9728@163.com), Sheng Li[1,2]; [1]Department of Psychology, Peking University, China, [2]Key Laboratory of Machine Perception (Ministry of Education), Peking University, China

Purpose: Motion repulsion (MR) refers to the exaggeration of perceived angular separation between two simultaneously presented stimuli that move in different directions. This phenomenon has been interpreted as an evidence for the mutual inhibition between direction-tuned neurons in visual cortex. Previous studies on perceptual learning (PL) have suggested that a consequence of extensive perceptual training is the modification of interneuron interaction. However, experimental evidence that supports this proposal is limited. Our study aimed to investigate the effect of PL of motion direction discrimination on the mutual inhibition between direction-tuned neurons by measuring the change in MR size before and after the training. Methods: The experiment consisted of a pre-training test phase (session 1-2), a training phase (session 3-8) and a post-training test phase (session 9-10). In the training phase, 32 participants were randomly assigned to one of four training groups (2 tasks × 2 base direction; tasks: luminance or direction discrimination; base direction: 240 deg or 300 deg). Classical 3-up-1-down staircase procedure was used during training. Constant stimuli method was used to measure participants' discrimination threshold and size of MR in the pre- and post- training tests. The stimuli were dynamic random-dot displays (coherence level: 100%, speed: 4 deg/s, stimulus diameter: 10°) generated with Movshon /Newsome algorithm (Pilly & Seitz, 2009). Results: (1) Training significantly decreased motion direction discrimination threshold along the trained direction. This learning effect transferred little to the untrained direction. (2) Motion direction discrimination training reduced bilateral MR size. (3) Luminance discrimination training did not affect the measured MR size, confirming that the aforementioned reduction of bilateral MR size cannot be attributed to the training induced attentional shift or adaptation. Conclusion: These results demonstrate that the lateral inhibition between motion direction-tuned neurons can be modulated by PL.

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Spatial vision: Crowding, eccentricity

Sunday, May 12, 8:30 am - 12:30 pm

Poster Session, Vista Ballroom

33.513 Acuity, contrast, eccentricity, and crowding

Daniel R. Coates[1](daniel.coates@berkeley.edu), Jeremy M. Chin[2], Susana T. L. Chung[1,2]; [1]Vision Science Graduate Program, UC Berkeley, [2]School of Optometry, UC Berkeley

It is well known that acuity is impaired by factors such as reduced stimulus contrast, viewing eccentricity, and interference from nearby contours (crowding). Despite numerous studies, a comprehensive quantitative characterization of these effects, including any interactions, remains lacking. We measured threshold letter size (acuity) for 150-ms tumbling-E targets at the fovea and lower visual field at eccentricities of 3, 5, and 10° for 5 subjects. Targets were presented in isolation or flanked on all four sides by randomly-oriented tumbling-Es at six center-to-center spacings (1.2-5x the letter size). Weber contrast of the entire stimulus varied from -2.5% to -99% in eight logarithmic steps. We find that across subjects, contrasts, and eccentricities, flanked acuity can be well described as a function of nominal flanker distance. A parsimonious characterization is a two-line fit in log-log space comprising a flat portion where flankers do not affect target recognition, and, within the absolute critical spacing for crowding, a line with constrained slope of -1. Except where crowding is essentially absent (foveally), average r2 for this fit is 0.85±0.17. Interestingly, contrast reduction causes only a modest (<1.5x) increase in the critical spacing, instead primarily elevating the flat portion of these curves. For all combinations of contrasts and flanker spacings, threshold acuities are linear functions of eccentricity (average r2=0.94±0.069). The critical spacing is also linearly related to eccentricity (average r2=0.98±0.038). Finally, a two-line fit relating acuity to contrast is consistent across subjects and eccentricities (average r2=0.88±0.048), yielding a power-law with exponent of -0.55 for contrasts below approximately 20%. Contrast-dependent flanked acuity for 224 conditions can be parameterized with just three per-subject values: baseline acuity, high-contrast flanked E2 and high-contrast unflanked E2. Except for slight increases in the crowding zone for low-contrast stimuli (at 2.5%, 1.5x greater than at 99%), crowding and contrast limit acuity independently.

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33.514 Orientation Discrimination in Periphery: Surround Suppression or Crowding?

Mingliang Gong[1](gongmliang@gmail.com), Lynn Olzak[1]; [1]Department of Psychology, Miami University

Both surround suppression and crowding show impaired perception when targets are presented in periphery. They have been treated as different phenomena because they vary in many properties. For example, an inward/outward asymmetry of "masking" is found in crowding but not surround suppression. However, different stimuli and tasks (detection in surround suppression vs discrimination or identification in crowding) are employed when examining inward/outward asymmetry in the two phenomena. Surround suppression uses large surround annuli and detection tasks. Crowding experiments use small localized nearby "masks" and discrimination or identification tasks. Therefore, it's unclear whether the discrepancy derives from the different stimuli or the different tasks. The current study was designed to disentangle the effects of stimuli and tasks. In the experiment, participants were required to perform an orientation discrimination task on center-surround stimuli using only the right eye. Fixation points were displaced 9 degrees to the left or right of the target center. On a given trial, one of two sharp-edged, 40-minute, 4 cpd grating stimuli appeared. The observer rated certainty of leftward vs. rightward tilt on a six point scale. Performance was measured in d'. In addition to the above control condition, two masking conditions were also run, each with a hemi-annulus mask surrounding the target on the left or on the right of the target (Petrev, Popple & McKee, 2007). Preliminary data showed a strong asymmetry effect, suggesting that task is the important variable in distinguishing between crowding and surround suppression. However, a large contrast-suppression effect was also observed, as is characteristic of surround suppression but not crowding. It may be that our particular combination of task and surround reveal a neural mechanism that differs from either surround suppression or crowding.

33.515 Electrophysiological signatures of crowding are similar in foveal and peripheral vision

Vitaly Chicherov[1](vitaly.chicherov@epfl.ch), Michael H. Herzog[1]; [1]Laboratory of Psychophysics, Brain Mind Institute, École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland

Flankers can strongly deteriorate performance on a visual target (crowding). For example, vernier offset discrimination strongly deteriorates when neighbouring flankers are presented. Interestingly, performance for longer and shorter flankers is better than performance for flankers of the same length as the vernier. Based on these findings, we proposed that crowding is strongest when the vernier and the flankers group (same length flankers) and weaker when the vernier ungroups from the flankers (shorter or longer flankers). These effects were observed both in foveal and peripheral vision. Here, using high-density EEG, we show that electrophysiological signatures of crowding are also similar in foveal and peripheral vision. In both foveal and peripheral (3.9°) vision, the N1 wave correlated well with performance levels and, hence, with crowding. Amplitudes were highest for the long flankers, intermediate for the short flankers and lowest for the equal length flankers. This effect was observed neither at earlier stages of processing, nor in control conditions matched for stimulus energy. Effects are more pronounced in the fovea than in the periphery. These similarities are evidence for a common mechanism of crowding in both foveal and peripheral vision.

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33.516 Sparse coding as a tool for gathering image statistics in peripheral vision

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Introduction: Form vision is significantly impaired in the periphery. It has been proposed that this is due to the learned statistics in the periphery being confounded by saccadic eye movements. We use sparse coding to capture natural image statistics. We train one basis with the confounding effects of saccades and one without. We then compare the encoding performance of these two bases to see if they can replicate the deficiencies of the periphery, particularly crowding. Methods: We produced videos that replicate the input to the entire crowding zone at an eccentricity of 5deg during a saccade. The movies last 66ms, with a saccade beginning between 40 and 60ms, corresponding to the time we hypothesize that the periphery learns image statistics under the spotlight of attention. We trained one

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basis on these videos and another basis on still natural image movies of the same duration. We then used these basis sets to encode artificial stimuli. The stimuli consisted of a white target in the center of a gray background with added white noise. We trained a linear SVM to classify the encoded stimuli. We then used this SVM to classify similarly encoded movies with the presence of a flanker. Results: We found that there was a significant crowding effect with the saccadic basis, that is, the further away the flanker was from the target the better the classification performance. We found that the still basis outperformed the saccadic basis; however there was evidence of crowding with the still basis as well. We further found that the saccadic basis preformed worse in the direction of the saccade than in the tangential direction, reproducing another characteristic of crowding. Conclusion: Sparse coding provides a viable method to study the interaction of image enocoding and crowding in peripheral vision.

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33.517 Large Interaction Zones for Visual Crowding for Briefly Presented Peripheral Stimuli

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Introduction: The extent of interaction (EoI) in visual crowding is the region around the target within which the presence of flanking stimuli compromises identification of the target. Following results reported by Tripathy and Cavanagh (Vision Research, 42, 2357-69, 2002), the current study systematically investigates the influence of stimulus duration on the EoI. Methods: The target (lower visual field, 10 deg eccentricity) was a 'T' in one of four orientations. The flankers were four "square thetas" in one of two orientations. On each trial there was one flanker in each cardinal direction relative to the target, except for interleaved unflanked trials, which measured uncrowded performance. Stimulus duration (13 - 427ms) varied between blocks of trials. Target size was fixed for all stimulus durations and contrast was adjusted so that unflanked target-orientation identification was 90 - 100% correct. The flankers matched the target in width, height and contrast. Within a block, 7 equally spaced target-flanker separations were presented using the Method of Constant Stimuli to obtain full psychometric functions for 3 observers (% correct report of target orientation vs. separation) for each stimulus duration. Psychometric functions were fit by a cumulative normal function (lower asymptote = 25%; upper asymptote = unflanked performance) and EoI was estimated as the separation that yielded a drop, relative to unflanked performance, of 10% of the amplitude of the psychometric function. Results: The radius of the EoI decreased from 6.6 deg (27ms duration) to 2.8 deg (427ms duration), despite almost constant visibility of the unflanked target at all durations. Conclusions: The duration of the stimulus has a substantial influence on crowding, with spatially larger mechanisms being invoked when processing brief stimuli. Subsequent experiments investigate the characteristics of these large mechanisms and their implications for Bouma's Law.

33.518 Visual acuity performance for luminance-modulated and contrast-modulated Cs and letters in the periphery: what crowds best?

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Foveal visual acuity is ~3x worse for contrast-modulated (CM) than for luminance-modulated (LM) Cs and shows greater magnitude and extent (in arcmin) of contour interaction, which is more robust to blur (Hairol et al, VSS2010; Waugh et al, VSS2011). In agreement with Wong et al (2001), these findings suggest that CM stimuli may be useful for earlier detection of anisometropic amblyopia. In this study, we examine contour interaction and crowding on visual acuity for foveal and eccentric (2.5, 5 and 10 deg) viewing, giving insight into strabismic amblyopia (Levi & Klein, 1982). Depths and extents of contour interaction and crowding were assessed by comparing performance for a C with and without surrounding bars, and for HOTV letters with and without surrounding bars or letters, as per Flom (1963). With eccentric viewing, the isolated letter generating 80-90% performance for CM stimuli was ~3x bigger than for LM stimuli, but to discriminate the direction of the C it was larger than to recognize HOTV letters, particularly eccentrically. When Cs and letters were surrounded by bars, performance dropped 20-45% across eccentricity; for Cs, slightly more for CM than LM stimuli. When letters were surrounded by letters, performance dropped more (40-60%), "bottoming out" at small eccentricities. Extents (arcmin) of interaction were greater at the fovea for CM stimuli, however with eccentric viewing, they were similar for LM and CM stimuli at roughly 0.5x the eccentricity, following Bouma's Law. These results suggest that C and letter acuities tap into different underlying processes; the C reflects resolution and positional uncertainty; the letters reflect shape discrimination, extracted at a later common stage for LM and CM stimuli. Letters surrounded by letters near the visual acuity limit show stronger crowding effects, but they are similar for LM and CM stimuli, at least in normal peripheral vision.

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33.520 The radial and tangential extent of spatial metamers

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Crowding provides a striking example of the limits of peripheral vision: objects are unrecognizable when spaced closer together than half their eccentricity. It has been suggested that crowding arises because the visual system summarizes spatial information in the periphery statistically (Parks et al., 2001; Pelli & Tillman; 2008; Balas, Nakano, & Rosenholtz, 2009). To test this hypothesis, we previously developed a physiologically-inspired model, in which an image is represented by receptive fields that tile the visual field, grow in size with eccentricity, and combine inputs from primary visual cortex (V1) to represent local higher-order statistical features (Freeman & Simoncelli, 2011). When model receptive fields were set to sizes found in primate area V2, we found that physically distinct images with identical model responses were indistinguishable − metameric − to human observers. The model provides a quantitative explanation of the dependence of crowding on eccentricity and spacing; here, we generalize it to address the fact that crowding is more pronounced radially than tangentially (Toet & Levi, 1992). We generate pairs of synthetic images matched for model responses within spatial regions, while independently controlling the scaling of these regions (s, ratio of radial extent to eccentricity), and their aspect ratio (a, ratio of radial to circumferential extent). If metamerism depends only on receptive field area (s2/a), combinations of scaling and aspect ratio that yield comparable areas should yield comparable performance. Instead, performance depends strongly on aspect ratio. Images are metameric when matched for moderate scaling ($s \approx 0.4-0.5$) and moderate radial elongation ($a \approx 1.5-2$), whereas images matched for much smaller scaling ($s \approx 0.25$) and tangential elongation ($a \approx 0.5$) are reliably discriminated. As in our original experiment, region sizes that yield metamerism are consistent with receptive field scaling in V2, and additionally rely on receptive field radial elongation, offering a new prediction regarding receptive field shapes in V2.

33.521 Temporal processing overcomes spatial crowding in the fovea

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It is widely accepted that in the fovea, crowding does not exist or it only occurs over very small distances. Our recent finding that spatial and temporal crowding are correlated, suggesting tradeoff between spatial and temporal processing, led us to hypothesize that limited temporal processing should result in increased crowding. We measured the crowding effect on an E target presented for 30, 60, 90, and 120 ms. The spacing between the target and the surrounding E was one letter spacing. To measure the temporal effect on crowding, we performed another experiment in which a mask was presented after the crowded target (backward masking, BM) using an inter-stimulus interval (ISI) of 30, 40,50, 60, 90, and 120 ms. In both experiments we measured the percentage of correct (PC) and the reaction time (RT). The results show that whereas a small crowding effect is found only with a short duration of 30 ms, RT was significantly slower in all crowded presentations by about 50 ms for all presentation times. Moreover, when BM was used, a significant crowding effect was found for both 30 and 60 presentation times and for all durations and ISIs. The maximal effect of BM was for ISI=30 in which PC was reduced from 93% to 67%. This effect was reduced with increasing ISI values, reaching a reduction in PC from 100% to 85%. Similarly, the RT was significantly slower for all conditions by more than 100 ms. Thus, the results show that absent crowding in the fovea is achieved but by a further processing time (increased RT) that overcomes the spatial crowding. When the processing is interrupted by backward masking, the spatial crowding is revealed. Thus, crowding exists throughout the visual field, but efficient temporal processing in the fovea eliminates the crowding.

Acknowledgement: Israel Science Foundations (ISF)

33.522 Orientation discrimination in complex stimuli: Crowding or surround suppression?

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We performed a meta-analysis of suprathreshold discrimination experiments with overlaid and surround "masks" performed our lab over the past decade. We compared our results to those found in crowding and in masking experiments to determine which phenomenon they more closely resembled. Overlay masking, lateral interactions, surround suppression, and crowding all reduce performance in many psychophysical tasks, but also show distinctive differences suggesting that they are separate processes with different neural substrates (Levi, 2008; Petrov, Popple & McKee, 2007). We describe a series of previously reported and new fine spatial frequency and orientation discrimination results that show reduced performance in the presence of "masks", but taken together, do not fit neatly into either of these categories. In all experiments, observers were highly trained, experienced undergraduates naïve to the purpose of the studies. In most studies, observers discriminated between 2 sinusoidal patterns. On any one trial, a single stimulus was presented. Highly experienced, naïve observers rated their certainty, on a six-point-scale, that pattern A or B had been presented. Performance was measured in d'. In different studies, test and "mask" stimuli were overlaid, were center-surround patterns that abutted or not, were 1st order luminance-modulated gratings or 2nd order contrast-modulated gratings or a mixture, differed in apparent depth or were in the same plane, were in or out of phase, differed in mean luminance, etc. The collective results provide a rich set of fairly homogeneous data, collected under identical laboratory conditions in, to describe characteristics of the mechanisms underlying fine spatial discriminations. Our results resembled both phenomena in some, but not all respects. The comparison is limited in that our experiments were foveal, where it is not clear that crowding occurs at all. In a companion poster, Mingliang Gong (VSS 2013, under review) presents new orientation discrimination data collected under peripheral viewing conditions.

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33.523 A high-dimensional pooling model accounts for seemingly conflicting substitution effects in crowding

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Visual crowding is a phenomenon in which the perception of a peripheral target depends on nearby, task-irrelevant flankers. The exact nature of this dependency is controversial (Whitney & Levi 2011). Phenomenologically, some flanker features appear to be confused, or substituted, with target features. One current debate (akin to early- vs. late-selection debates in attention) centers around whether substitution occurs for entire objects, for basic features, or something in between. Results have been mixed: in letter stimuli, observers sometimes appear to swap the target with entire flankers (van den Berg et al. 2012), to preferably swap with similar flankers, or to report letters not present in the display (Freeman et al. 2012). In feature conjunction stimuli, observers appear to swap unbound features (Põder & Wagemans 2007), whereas in stimuli of intermediate complexity observers appear to lose location information after binding simple features (Greenwood et al. 2012). We ask whether a high-dimensional pooling model can predict these seemingly disparate results. In this model (Balas et al 2009), the visual system measures a texture descriptor (Portilla & Simoncelli 2000) in each local pooling region. We test whether the ambiguities and confusions inherent in this representation can account for diverse substitution phenomena. To do this, we synthesize new images ("mongrels") which share the same texture descriptor as the original stimuli. We find that the model explains seemingly contradictory results. In mongrels of "complex" letter stimuli, we observe swapping of flankers with targets, preferred generation of similar flankers, and synthesis of absent letters. Mongrels of simple feature conjunction stimuli show illusory conjunctions, supporting observations of non-binding of features. Mongrels of arrays of crosses (Greenwood et al. 2012), typically reproduce arrays of crosses, in line with apparent low-level "binding" in crowding of these stimuli. Thus, our high-dimensional pooling model can reconcile disparate crowding accounts.

33.524 Redefining the Metric of Visual Space: Visual Field Boundaries Influence Attentional Resolution and Crowding Performance

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Perceptual asymmetries exist for a variety of tasks. Here we show that one such asymmetry is explained by a new metric of visual space that is based on an individual's visual field borders. Sixteen subjects performed a crowding task in which they were required to judge the orientation of a grating presented above or below fixation, either alone or flanked by four similar gratings. Previous studies have shown that participants are better at judging the orientation of the crowded grating along the lower vertical meridian than the upper vertical meridian. It has been theorized that this asymmetry is due to differences in the resolving power of spatial attention that are biased toward the lower field due to ecological factors. However, the upper and lower visual fields are asymmetrically bounded, with upper visual field extents (VFE) smaller than lower VFE. The metric we propose takes this anatomical asymmetry into account, replacing degrees of visual angle with a distance measure that is relative to VFE for a given radial direction, termed percentage of visual field extent (%VFE). To assess whether this metric could account for perceptual asymmetries, we measured each participant's upper and lower VFE and used these values to compute %VFE for the 20° grating locations. The crowding displays were then presented at 20° above/below fixation and at matched locations (in units of %VFE) in the opposite hemifield. We found that the asymmetry in crowding performance was largely accounted for by individual variability in visual field extent ($R2=0.54$). Importantly, this asymmetry is eliminated when the locations of stimuli are equated using the new metric (i.e., locations with equal %VFE). These results challenge the assumption that degrees of visual angle is the most appropriate metric for visual space and suggest that attentional resolution in crowding is more symmetric than previously thought.

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33.525 Crowding with invisible flankers – a reexamination

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Crowding is a key limiting factor of form vision in the periphery. The neural origin of crowding is unclear. How awareness of flankers affects crowding can inform the origin of crowding. However, results in the literature appear conflicting. Gratings rendered invisible by interocular suppression (IOS) produce crowding (Ho et al., 2011; Shin & Tjan, 2011 VSS); letters rendered invisible by adaptation-induced blindness (AIB) do not (Wallis et al., 2011). We re-examined these findings while eliminated stimulus difference as a factor. We rendered flankers invisible with IOS in Exp1 (gratings) and Exp2 (letters), and with AIB in Exp3 (gratings). In Exp1 and 2, we presented a target with up to 4 flankers to the non-dominant eye and four high-contrast dynamic concentric checkerboards to the dominant eye to suppress the flankers. Subjects discriminated orientations (clockwise/counter-clockwise) in Exp1 and identified letters in Exp2. They also reported the number of visible flankers. In Exp3, we presented 4 gratings (adaptors) at the flanker locations preceding flanker presentation (1 min initial and 5 s top-up adaptation). The orientations of adaptors were randomized within twice the subject's orientation threshold and jittered at 10 Hz. Tasks were the same as Exp1. We found that the accuracy of target identification decreased as the number of physical flankers increased when the flankers was rendered invisible by IOS (Exp1 and 2). However, in the case of AIB (Exp3), performance depended on the number of subjectively visible flankers. Our results are consistent with the literature but have eliminated stimulus difference as a factor. These findings imply that crowding starts before the neural locus of IOS and after that of AIB, and place the neural origin of AIB before that of IOS. Our results is consistent with the view that crowding starts as early as V1 and is exacerbated in higher visual areas.

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33.526 Dynamic components modulate crowding

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Crowding refers to impairment in target identification due to the proximity of adjacent objects, and likely reflects inappropriate feature integration. It is the major factor leading to compromised peripheral reading performance. Here, we examined whether crowding can be remediated with dynamic presentation. The dynamic components were introduced through zoom mimicking "zooming" in or out on a document. Specifically, we varied letter size monotonically while maintaining center-to-center letter separation. Although the spatial extent of crowding is size independent above recognition level (Pelli, Palomares & Majaj, 2004), we predict that the coherent expanding/contracting motion within each letter will facilitate feature separation between letters and feature integration within letters, and in turn reduce crowding. We expect greater benefits for smaller zoom ranges and reduced/negative benefits for larger zoom ranges due to spatial and temporal limits. Four subjects identified the middle flanked letters (1° print size) in random strings of three letters presented at 10° below fixation. Performance was measured at 6 letter separations (ranging from 0.8 to 3.2°). The spatial extent of crowding, calculated based on the letter separations

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yielding 80% accuracy, was obtained for five zoom ranges (0° (size remaining at 1°), 0.125° (size varying between 0.875° and 1°), 0.25°, 0.5°, 0.75°), two zoom directions (inward, outward), and two durations (222ms, 444ms). For each combination of zoom direction and duration, the zoom range corresponding to the smallest spatial extent of crowding (the peak benefit) was determined. Averaged across subjects, the peak benefit (~10% reduction in spatial extent of crowding) was found at the zoom range of 0.22° for inward zooming at 222ms (p = 0.014). The benefits were less pronounced or absent for the longer duration and for outward zooming. The results suggest that crowding in peripheral vision can be alleviated with dynamic presentation which likely facilitates target-flanker feature separation and integration.

33.527 **Saccades affect crowding, but crowding does not affect saccades** Girish Kumar[1](girish.kumar@berkeley.edu), Susana T. L. Chung[1,2]; [1]School of Optomety, UC Berkeley, [2]Vision Science Graduate Program, UC Berkeley

Aim: Recent research has shown a close association between saccades and crowding, specifically saccades reduce crowding. However, does crowding affect saccades? The aim of this study was to investigate the effects of crowding on the dynamics of saccades. Methods: We compared the dynamics of saccades (amplitudes, latencies, accuracy and precision of landing positions) when subjects (N=3) executed saccades to the center of a stimulus target, located at either 10° in the lower visual field or 10° in the lower-right visual field. Different types of stimuli were tested: a 0.25° square, single letters, random sequences of three letters (trigrams), a small and a large solid rectangle and a small and a large Gaussian blob. Letters were rendered in Times New Roman with x-height = 0.75°. The size (and standard deviation) of the small and large rectangles and Gaussian blobs matched the average size of a single letter and a trigram, respectively. Eye movements were monitored using an Eyelink II at a sampling frequency of 250 Hz. Saccades were identified using a velocity criterion of 75 °/second. To ensure that subjects experienced crowding at both testing locations, we separately measured letter identification accuracy for single letters and for the middle letters of trigrams, presented for 150 ms. Results: On average, performance accuracy dropped from 99% for identifying single letters to 40–55% for identifying the middle letters of trigrams, confirming that our letter-stimulus conditions were effective in inducing crowding. However, there was no difference in any of the parameters of the dynamics of saccades between the single-letter and the trigram conditions. In fact, none of the parameters of the dynamics of saccades were statistically different across the different stimulus types (p>0.05 after Bonferroni corrections). Conclusions: While saccades affect crowding perceptually, the reverse is not true. Specifically, crowding does not alter the dynamics of saccades.

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33.528 **Visual crowding is altered during smooth pursuit eye movements** William Harrison[1](willjharri@gmail.com), Roger Remington[1], Jason Mattingley[1,2]; [1]School of Psychology, The University of Queensland, [2]Queensland Brain Institute, The University of Queensland

Visual crowding is normally measured while observers maintain fixation, leaving open the question of whether changing eye position signals can modify crowding effects. Here we measured the spatial extent of crowding during voluntary smooth pursuit eye movements, and compared the effects with those obtained at the same eccentricity during steady fixation. Observers pursued a fixation spot that translated at 10°/sec, either rightward or leftward, or they fixated a spot that remained stationary in the center of the display. A visual probe ("T", oriented up, down, left, or right) was presented for 47 ms to the left or right of fixation with equal probability. Other letters served as flankers, and, for pursuit trials, all stimuli translated across the screen with the pursuit target to minimize retinal motion. Probe-flanker separation was varied systematically, and the proportion of correct probe orientation discriminations across separations was modeled using two-parameter log functions to derive the critical spacing of crowding. Critical spacing was calculated separately for probes located contraversive and ipsiversive to the direction of the eye movement. Relative to the fixation condition, critical spacing increased when the probe was 3° from the pursuit target, but only when the probe was positioned contraversive to the direction of pursuit. By contrast, there was no change in critical spacing when the probe was positioned 7° from the pursued target. Control experiments ruled out any contribution from directional differences in either the perceived position of stimuli or visual attention. Thus, extra-retinal signals related to the generation of smooth pursuit eye movements increase the spatial extent of visual crowding contraversive to the direction of pursuit and relatively close (~3°) to the fovea. This selective expansion of the zone of crowding may attenuate the salience of background objects, and thus facilitate tracking of a target object during smooth pursuit.

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33.529 **The meridian effect on the cortical magnification factor for visual word form identification** Li-Ting Tsai[1](d96429003@ntu.edu.tw), Chien-Chung Chen[2], Yuh Jang[1], Kuo-Meng Liao[3]; [1]School of Occupational Therapy, College of Medicine, National Taiwan University, Taiwan., [2]Department of Psychology, National Taiwan University, Taiwan., [3]Department of Endocrinology and Metabolism, Zhongxiao Branch, Taipei City Hospital, Taiwan.

Previous studies of visual word form identification focused on the performance in the foveal vision. However, several eye diseases, such as age-related macular degeneration and diabetic retinopathy, would cause central vision problems. Improving peripheral form vision, such as eccentric viewing training and peripheral perceptual learning, is an important visual rehabilitation method for people with central visual deficit. The alternative location of foveal vision depends on the deficit position and personal preferred retinal loci. To develop a tool to assess the ability of word identification in all meridians, we thus measured the size threshold for identifying visual word forms in the fovea and eccentric vision on vertical and horizontal meridians. The stimuli were16 traditional Chinese characters selected for similarity in legibility and coverage of different spatial configurations. The characters were presented at the fovea, and at 1 degree, 2 degrees, 4 degrees, 6 degrees, and 8 degrees eccentricity in the upper, lower, right, and left meridians. The task of the observer was to press a key to indicate the corresponding character. Five observers with normal visual acuity were tested either monocularly, or binocularly. At every location, the size threshold was measured with a staircase procedure at four to seven contrast levels (10-80%). The fitted cortical magnification factors ("E2") on the vertical meridian was significantly smaller than those on the horizontal meridian. E2 on the upper median was smaller than that on the lower meridian. Such asymmetry was not found between the left and the right meridians. E2 in the binocular condition depended on both meridian and contrast. In sum, there is different meridian effect on the cortical magnification factors between the vertical and horizontal meridians and between monocular and binocular viewing. This latter suggests that a nonlinear binocular contrast summation process was involved in the meridian effect.

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Face perception: Emotion

Sunday, May 12, 8:30 am - 12:30 pm

Poster Session, Vista Ballroom

33.530 **Exploring the left eye bias for faces** Elina Birmingham[1](ebirming@sfu.ca), Dawn Chan[1], Victoria Kling[1], Dominic Trevisan[1]; [1]Faculty of Education, Simon Fraser University

Observers show an attentional bias for the left visual field (LVF) relative to the right visual field (RVF) of face stimuli (e.g., Butler et al., 2005 Neuropsychologia). Recent work using the Moving Window Technique (MWT) revealed that a specific bias to explore the eye region within the LVF (LVF-eye) emerges at 11-12 years of age and reaches significance in adulthood (Birmingham, Meixner, Iarocci, Kanan, Smilek, & Tanaka, in press at Child Development). The present study examined whether the LVF-eye bias is modulated by the type of expression (basic vs. complex expressions). In the MWT, the observer explores a blurry face with a mouse-controlled window of high-resolution information. Experiment 1: 64 images consisting of four basic expressions (happy, angry, fearful, disgusted) were presented (n=17). Experiment 2: 20 images of basic (e.g., sad, afraid, angry) and complex (e.g., admiring, guilty, flirting) expressions were presented (n=9; preliminary data). In both experiments, the starting position of the exploration window was counterbalanced, occurring to the left or the right of the face on alternating trials. Experiment 1: the LVF-eye was explored more than the RVF-eye (LVF-eye M=0.24 vs. RVF-eye M=0.16), p<0.05. The bias to explore the LVF-eye did not vary as a function of emotion (happy, angry, fearful, disgusted). In Experiment 2, the LVF-eye bias was stronger for complex expressions (LVF-eye M=0.25 vs. RVF-eye M=0.19) than for basic expressions (LVF-eye M=0.22 vs. RVF-eye M=0.20), p<0.05. Exploration of the mouth was reduced for complex expressions relative to basic expressions. The LVF-eye bias is enhanced for complex expressions, suggesting a functional role in expression recognition.

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33.531 Fear recognition in four patients with focal bilateral amygdala damage

Frederic Gosselin[1](gosselif@googlemail.com), Michael Spezio[2], Ralph Adolphs[3]; [1]Département de psychologie, Université de Montréal, [2]Psychology, Scripps College, [3] Humanities and Social Sciences, Caltech

Bilateral damage to the amygdala can lead to a dramatic impairement in fear recognition through an inability to gaze at and utilize information about the eye region of faces (Adolphs et al., 2005). Here, we extended these findings by applying the Bubbles method, which asks viewers to discriminate happy and fearful faces from randomly sampled small regions of a face, with concomitant gaze tracking, to a group of four rare patients with focal bilateral amygdala damage (including new sessions with SM, the amygdala patient examined in Adolphs et al., 2005) as well as 20 healthy controls. Two of the amygdala patients behaved indiscriminably from healthy controls (JF and BG), while the other two (SM and AB) required an unusually large number of face samples to attain target performance, and neither gazed at nor made use of the eye region. Repeatedly instructing the two impaired amygdala patients to look at the eyes in faces reduced the number of face samples required to reach target performance within the range of healthy controls, and led these patients to gaze at and to use the eye on the right side of the face stimuli. In contrast, this instruction had little impact on the other amygdala patients and on healthy controls. We will argue that these distinct behavioral profiles found in amygdala patients are due to slight differences in their lesions.

33.532 Implicit facial emotion recognition in a case of cortical blindness

Christopher L. Striemer[1](striemerc@macewan.ca), Robert L. Whitwell[2], Melvyn A. Goodale[2]; [1]Department of Psychology, Grant MacEwan University, Edmonton, Alberta, Canada, [2]The Brain and Mind Institute, The University of Western Ontario, London, Ontario, Canada

Previous research has suggested that recognition of fearful faces may be carried out by pathways that bypass primary visual cortex (V1) and project to the amygdala. Some of the strongest evidence supporting this claim comes from two previous case studies of "affective blindsight" in which patients were able to correctly guess whether an unseen face was depicting a fearful or happy expression. In the current study we report a new case of affective blindsight in patient MC who is cortically blind following extensive bilateral lesions to V1 and most of her ventral stream. Despite her large lesions MC has preserved motion perception which is related to sparing of the motion sensitive region MT+ in both hemispheres. To examine affective blindsight in MC we asked her to perform gender and emotion discrimination tasks in which she had to guess, using a two alternative forced-choice procedure, whether the face presented was male or female, or was depicting a happy vs. fearful, or a happy vs. angry expression. Finally, we also asked MC to perform a four alternative forced-choice target localization task in which she simply had to guess whether a target (a large circle) was presented on the top, bottom, left, or right of a computer screen. Results indicated that MC was not able to determine the gender of the faces (51% accuracy), or localize targets (29%). However, MC was able to determine, at significantly above chance levels, whether the face presented was depicting a happy or fearful (67%, p=.006), or a happy or angry (64%, p=.025) expression. These data lend further support to the idea that there is a non-conscious visual pathway that bypasses V1, as well as higher-order face processing regions in the ventral stream, that is capable of processing affective signals from facial expressions.

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33.533 Fearful faces: no emotion-based processing without awareness under continuous flash suppression.

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Studies using continuous flash suppression (CFS) suggest that emotion-laden stimuli, such as fearful faces, are prioritized when presented outside of awareness. For example, fearful faces gain faster access to awareness from CFS suppression than other expressions (Yang, Zald & Blake, 2007) and emotionally salient images rendered invisible by CFS guide spatial attention to a subsequent target (Jiang, Costello, Fang, Huang & He, 2006). Such findings have been attributed to a specialized, sub-cortical pathway that evaluates the emotional significance of stimuli, without awareness, to direct processing resources (Tamietto & de Gelder, 2010). In two studies, we tested whether the emotional content of faces presented under CFS (i) provides prioritized access to awareness or (ii) directs spatial attention. In Experiment 1, control images were created via spatial inversion and contrast sign reversal to produce stimuli that maintain the low-level image properties of normal facial expressions, but whose recognizable emotional content is vastly reduced. Normal and control face stimuli were presented briefly (800 milliseconds) under CFS. Fearful faces broke suppression more often than other facial expressions. However, in accordance with previous work (Gray, Adams, Hedger, Newton & Garner, in press) a similar effect was found with the control stimuli, suggesting that this "fear advantage" is explained by low-level image differences across expressions rather than by unconscious evaluation of emotional content. In Experiment 2, we employed an attentional cuing paradigm with CFS to examine the impact of unconsciously presented face stimuli on spatial attention. Fearful faces modulated attention in trials where they broke suppression, such that discrimination of a subsequent, co-located probe was improved. However, facial expression failed to modulate attention when observers were unaware of stimuli. Data from both experiments cast doubt on the notion that the emotional meaning of faces is processed unconsciously.

33.534 Ensemble coding of facial emotion and social anxiety

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Emotion estimation of facial crowds is crucial in judging other people's moods, especially when faced with others people's evaluation. This is particularly relevant for social anxious individuals, given that fear of evaluation is a key feature in social anxiety. The current study investigated how people's overall emotion judgments of facial crowds are related to social anxiety. We presented 6, 12, or 24 faces expressing either anger or happiness for either 100 ms (Experiment 1) or 1000 ms (Experiment 2). We varied the ratio between angry and happy faces from 1:5 to 5:1 in five levels. The participants' task was to judge whether the overall emotion of the display was positive or negative. The proportion of negative responses was plotted against the valence ratio between angry and happy faces. We then found a function to describe the relationship between each participant's responses and the valence ratio. Based on these psychometric functions, we estimated each participant's point of subjective equality (PSE) and precision (standard deviation of the psychometric function). In Experiment 1, we found that the participants' PSEs were negatively correlated with their levels of social anxiety. However, no relation was found between precision and social anxiety. To better understand the significant relation between the PSEs and the levels of social anxiety, we categorized the participants into two groups depending on their levels of social anxiety. The PSEs of high social anxiety group did not significantly differ from the veridical ratio of 0.5, whereas those of low social anxiety group did significantly differ from it. We replicated these findings in Experiment 2 in which participants were selected based on their levels of social anxiety. Thus, socially anxious individuals lack positive biases that are present in non-anxious individuals and perceive the overall emotion of crowds more negatively.

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33.535 Singular or Summary: Averaging of Facial Expression in Sets is Modulated by Eccentricity

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The visual system is believed to compress and represent abundant information through averaging. For example, when observers were asked to judge the orientation of a singular Gabor patch that was surrounded by others, the judgement approached the mean orientation of all Gabor (Parkes, Lund, Angelucci, Solomon, & Morgan, 2001). Recently, a similar effect was reported in complex face stimuli, where observers appeared to summarise the mean emotion when presented with a set of faces but were unable to identify the emotion in each individual (Haberman & Whitney, 2009). In our study, we investigated the relationship between eccentricity and averaging of emotional expression. The stimuli were created by morphing neutral with happy/disgusted expressions, where the resulting images ranged from 0 to 100%. The target face was either shown in isolation (baseline) or surrounded by eight flankers of the same identity. The flankers' expression was either identical to the target or different from it (e.g. flanker 60% disgusted vs. target face 40% disgusted). The degree of difference between the target and flanker was varied from 0 to 100%. These were presented either centrally, or parafoveally. We asked observers to judge the emotional strength presented on the target face, on an 11-point scale. The effect of flankers was assessed

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by calculating the deviation between actual response and the emotion on the target face. We found a much larger significant effect of difference in the parafoveal location, where errors increased as a function of the difference in emotion within the set, which leaned towards the average emotion of the set. The results suggest that averaging of facial information is modulated by eccentricity. Haberman,J.,&Whitney,D.(2009).Seeing the mean: Ensemble coding for sets of faces. Journal of Experimental Psychology: Human Perception and Performance,35(3),718-734. Parkes,L.,Lund,J.,Angelucci,A.,Solomon,J.A.,&Morgan,M.(2001).Compulsory averaging of crowded orientation signals in human vision. Nature neuroscience,4(7),739-744.

33.536 Emotion recognition (sometimes) depends on horizontal orientations

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Face recognition depends critically on horizontal orientations (Dakin, 2009). Presently, we asked if facial emotion recognition also exhibits this dependency. We measured observers' performance at classifying happy and sad faces that were filtered to include predominantly horizontal information, predominantly vertical information, or both. In addition, we used picture-plane rotation (0 or 90 degrees) to dissociate image-based orientation energy from object-based orientation. We recruited participants to complete two emotion recognition experiments using orientation-filtered faces. In Experiment 1 (N=17), we measured the speed of correct emotion categorization using genuine happy/sad faces. In Experiment 2 (N=21), we used posed emotions to control for confounding features in genuine emotions (open/closed mouths). In both tasks, participants viewed stimuli in a fully randomized order for 2000ms each and classified facial emotion as quickly and accurately as possible. Picture-plane orientation varied across experimental blocks, and filter orientation, emotion, and open/closed mouth position (Experiment 2) were randomized within blocks. The results of Experiment 1 revealed main effects of emotion ($p<0.001$) and filter orientation ($p<0.001$), with longer response latencies to sad faces and vertically-filtered faces. We also obtained an interaction between emotion and filter orientation ($p<0.01$); vertical filtering only affected sad faces. In Experiment 2, we replicated the main effects of emotion and filter orientation, and observed main effects of mouth position (open <closed, $p<0.001$) and picture-plane orientation ($p<0.001$). Critically, we observed a three-way interaction between emotion, mouth position, and orientation filter ($p<0.001$) such that the disadvantage for vertically-filtered faces disappears for open-mouthed happy faces. We conclude that emotion recognition does depend on horizontal orientations, but this varies according to emotion category and specific pose. Furthermore, the lack of any interaction between image and filter orientation suggests that raw orientation (as computed by V1) does not dictate performance, but filter orientation relative to the face does.

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33.537 Using Reverse Correlation to let Adults and Children Show us their Emotional Expression Templates

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Reverse correlation with sinusoidal noise is a method useful for estimating the information used during facial emotion classifications. As yet, this method has not been used to test for developmental differences in processing strategy during face classification. We had adult and 7-10 year old participants classify a neutral face (either the Mona Lisa or a neutral face from the NimStim set of faces) overlaid with random sinusoidal noise as either happy or sad. Over relatively few trials, classification images and subsequent quantitative analyses revealed that the information necessary to turn a neutral face into an expressive one differs for adults and children, but not for both stimuli. For the Mona Lisa face, adults and children performed similarly, relying on mid-high spatial frequencies for their classifications. For the real neutral face, adults relied more on lower spatial frequencies, whereas children relied on higher spatial frequencies; this pattern matches data from more traditional experiments. Super-subject data bolster these results, and demonstrates the consistency between 2AFC and 4AFC tasks. For both adults and children, critical regions for classification were not only present around the corners of the mouth, but also on the cheeks, between the eyes, and around the corners of the head. Overall, results indicate that children between 7-10 years employ immature processing strategies within facial emotion processing, and that only real faces are capable of revealing these differences. More generally, reverse correlation is a useful technique for estimating perceptual templates in developmental populations.

33.538 Was "seeing the mean emotion" indeed a high level analysis?

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Introduction: Previous research found that observers could precisely extract summary statistics from a broad range of visual stimuli, including facial emotion. However, it is controversial whether the results found in the mean emotion discrimination task indeed showed a kind of high level analysis. The task was adapted from the low level ensemble coding, like mean size (Ariely, 2001; Chong, & Treisman, 2003). Does it really reflect the high level extraction of mean emotion? Methods: Two experiments were designed to address this question. Fifty morphed faces were created from two emotionally extreme faces (neutral to disgust) of the same person. In Experiment 1, the same task of Haberman and Whitney (2007, 2009) was used. Observers were asked to judge whether a single test face was more neutral than the preceding set of four faces with identical or different emotions displayed for 2000ms. In Experiment 2, observers made similar comparison, but based on the size of eyes within the faces. Results: The threshold analysis used by Haberman and Whitney (2007, 2009) didn't show a consistent pattern for every subject. Therefore, A', the nonparametric sensibility index of signal detection theory, was calculated as the index of discrimination performance. The results showed that although observers could indeed precisely discriminate the mean emotion of four hetero faces from the emotion of the test face, discriminating the emotion of homo faces was much better. Besides, compared with previous results (Haberman, & Whitney, 2007, 2009), the mean discrimination performance showed no differences among upright, inverted and scrambled faces (Haberman, & Whitney, 2007, 2009). More importantly, the mean extraction of eye size was as precise as that of emotions. Conclusion: It was possible that the summary representation of facial expressions might be based on low level, instead of high level, visual analysis of faces.

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33.539 Recognizing Expressions: Are Static Displays Good Enough?

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Most research investigating children's recognition of facial expressions has involved static and isolated face stimuli. However, in the real world facial expressions are dynamic and viewed in the context of body movements, background scenes, etc. We examined the influence of bodies on children's and adults' perception of emotional expressions using both static and dynamic stimuli. Children's recognition of statically presented facial expressions is influenced by the accompanying postural expression (Mondloch, 2012; Mondloch, Horner, & Mian, 2012). However, recognition of dynamically presented facial expressions is not influenced by postural expressions (Nelson & Russell, 2011). That postural information influenced children's recognition when stimuli were static – but not dynamic – is surprising. To resolve these discrepant findings we examined the extent to which attention allocation is influenced by a) the expression cues available and b) whether the stimulus is static or dynamic. Children (4-9 years) and adults viewed four video clips in three conditions: face-only, body-only (i.e. face blurred), and face-body. Stimuli were presented on a Tobii eye tracker and participants freely labeled each video. For dynamic stimuli in the face-body condition, both groups looked almost exclusively to the face (>88% of the time for all emotions). In the body-only condition, both groups showed a reduction in looking to the face, with an especially large drop observed in children (from 90% to 50%). For static stimuli, adults looked less at the face both in the face-body condition (71%) and in the body-only condition (32%) than they did for dynamic stimuli. Children are currently being tested. These results indicate that for adults – and perhaps for children – attentional allocation varies for static versus dynamic emotional expressions. These data may explain why dynamic bodies do not influence emotion recognition whereas static bodies do, providing a more complete understanding of how emotion recognition develops in childhood.

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33.540 Dynamic mental models of culture-specific emotions

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According to the Universality Hypothesis, facial expressions of emotion comprise a universal set of six basic signals common to all humans (i.e., happy, surprise, fear, disgust, anger, sad; Ekman et al., 1969). In contrast, Jack et al.

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(2012) demonstrate that although Western Caucasians (WC) represent the six basic emotions with the same dynamic facial movements, East Asians (EA) do not. This raises the questions of (1) what are the basic emotions in the EA culture? and (2) what are the corresponding culture-specific facial signals of emotion transmission? To address the first question, we clustered emotion words in WC (English, 50 observers) and EA (Chinese, 50 observers) culture. Each participant rated on a bipolar scale the pairwise similarity of selected emotion words in their own language (see Methods). We applied clustering analyses to these data. The English clusters comprised 8 emotion categories including the six basic ones, plus pride and shame (e.g., Tracey & Robins, 2004). In contrast, the Chinese clusters showed a more complex structure of 10 basic emotions (see Figure S1). Using the resulting basic emotion categories as response labels, we applied 4-dimensional reverse correlation (Yu et al. 2012) to reconstruct culture-specific face signals that transmit each emotion. As in Jack et al. (2012), on each experimental trial the observer viewed a random facial animation generated by computer graphics platform. Observers interpreted the facial animation as expressive when the facial movements corresponded with their mental representation of that emotion (Figure S2). Reverse correlation analyses produced, for each observer, a dynamic model per basic emotion. Our analyses revealed culture-specific facial expression signals, refuting the University Hypothesis. For the first time, we also derive the cultural face signals that articulate emotion communication in the EA culture (see Figure S3 for examples).

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33.543 **Are compound emotions also basic emotion categories?**
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Research on the perception of facial expressions of emotion generally focuses on six theoretically basic categories: angry, happy, sad, fear, surprise, and disgust. Yet other facial expressions of emotion are regularly observed, e.g., appalled and angrily-surprised. Many of these emotion categories can be defined as combinations of the six basic emotions (e.g., appalled is the state of simultaneously feeling disgusted and angry). Here we ask whether facial expressions of compound emotions are perceived as the summed representation of different basic categories or as their own, distinct emotion categories. Participants (N = 23) completed a 3 alternative forced choice match-to-sample task, in which they viewed a target facial expression of emotion (1000 ms) and then selected a match from one of three test expressions (by key press). The target expression was either one of 17 compound emotions or one of the six basic emotions; test expressions consisted of two basic emotions and their compound. Results were highly consistent between participants and suggested that some compound emotions are perceived as distinct emotion categories, while others are likely represented as the sum of their two subordinate emotion categories. For example, participants were 83% correct when asked to discriminate angrily-surprised from anger and surprise (angry vs. angrily-surprised and surprise = 75% correct, surprise vs. angrily-surprised and angry = 61% correct), whereas recognition of appalled vs. angry and disgust was at chance (33%; angry vs. appalled & disgust = 55% correct, disgust vs. angry and appalled = 35% correct). These results may further suggest that some compound emotions are coded as a basic category by the visual system, which would have major implications in the study of face perception and emotion.

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33.544 **Look out! Gaze-cueing is greater from fearful faces in a dangerous context for children and adults**
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People shift their attention to follow where other people look; thus they are faster to respond to objects that are looked at (valid trials) than objects that are not looked at (invalid trials). Gaze-cueing is measured as the difference in RTs for invalid minus valid trials. In this study, we investigate whether non-predictive gaze-cueing is modulated by: facial expression (fearful, happy, neutral); the affective decision required about the gazed-at object (fear-relevant decision of dangerous versus safe animal, or a neutral control of blue versus orange bar); and SOA (300 or 700 ms). For the first time, we also investigate whether there are differences between adults and 8-12 year old children, who completed the fear-relevant decision condition only. Adults showed greater gaze-cueing from fearful than happy or neutral faces at both SOAs, but only in the fear-relevant decision condition. Like adults, children showed greater gaze-cueing from fearful than happy faces in the fear-relevant decision condition; however, this fear-advantage over happy faces was only observed at SOA 300, and there was no fear-advantage relative to neutral faces at either SOA. An additional analysis investigated whether responses overall differed for dangerous and safe animals. Adults responded faster to dangerous than safe animals when cued by a face (regardless of expression) but not when cued by a non-social stimulus (arrow), suggesting a social-specific advantage. Children however showed no advantage for dangerous animals regardless of cue type. Overall results suggest that 8-12 year old children are partially adult-like in that they show some fear-advantage for gaze-cueing when there is a dangerous context, but are not yet fully mature in their ability to integrate social and contextual information to drive shifts in attention.

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33.545 **Evidence for the Development of the Extended Face Network, Executive Function, and Response Inhibition: An FMRI Study of the Emotional Go/No-Go Task**
Elizabeth Toomarian[1](etoomari@ucsd.edu), Jarnet Han[1], Maha Adamo[1,3], Frank Haist[1,2,3]; [1]Center for Human Development, University of California, San Diego, [2]Psychiatry Department, University of California, San Diego, [3]Kavli Institute for Brain and Mind, University of California, San Diego

Faces are the foundation of the human visual social environment. Adult face expertise involves highly integrated functions between a core face network crucial for decoding perceptually invariant aspects of faces, and an extended face network that recruits specific cognitive systems depending on task demands. Recent evidence shows that the core continues to develop into adolescence; however, virtually nothing is known about the development of the extended face network. Here, we report FMRI findings from a cognitively demanding "Emotional Go/No-Go" task in which participants were presented faces showing disgusted, happy, and neutral expressions. Within a task run, either disgust or happy was defined as the "No-Go" stimulus (counterbalanced across runs), with the other emotion and neutral stimuli requiring a button-press response. A hybrid blocked/event-related design maximized prepotent responding while also allowing for the categorization of responses. Seventeen children (6-12 years; 9 females; mean 9.6 years), 14 adolescents (13-16 years, 5 females, mean 15.4 years), and 16 adults (18-34 years, 8 females, mean 22.4 years) were tested. Children and adolescents made more commission errors ("false alarms") than adults, and children made more errors than the adolescent group. Adults and adolescents performed similarly in responding correctly to "Go" stimuli, but children made fewer correct responses than adults. Nonetheless, children performed well above chance, indicating the ability to perform the task. Children showed significantly less activity in the amygdala during correct inhibition responses compared to adults and adolescents. During commission errors, children produced significantly less activation in bilateral anterior insula, bilateral inferior frontal gyrus, and right anterior cingulate. Overall, the findings have broad implications for the development of multiple brain systems supporting cognition. Specifically, we suggest that the networks for face emotion evaluation, executive function, and inhibitory processing in children have a protracted developmental trajectory that appears to extend into adolescence.

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33.546 **Matching emotional expressions of faces within an olfactory context: Does my own emotion matter?**
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Considering the role of the "mirror system" in human social cognition (Gallese et al., 2004), and the activation of the same brain areas during both feeling and seeing an emotion (e.g., the insula; Wicker et al., 2003), the ability to recognize facial expressions may imply the matching between self-produced emotions and those perceived in others. To investigate this question, we designed a task in which participants had to determine whether the emotion expressed by a centrally presented face match one of the expressions (anger, disgust, fear, happiness, sadness, and neutral) displayed by the same person in smaller-size photographs around the central one. Participants were asked to give an oral response in a microphone, but the microphone was used to administrate an odorant. Three olfactory contexts were used and counterbalanced between blocks and subjects: neutral, aversive, and pleasant. In order to evaluate whether the emotions elicited by these contexts modulate the detection thresholds of expressions, morphing were made between the neutral expression and all other emotions (every 10%, from 0% to 100%), and the central face expressed one intensity within one continuum. Results indicated great accuracy to match each expression, with detection thresholds depending on the emotion expressed, lower thresholds being observed for happiness, disgust, and fear. Interestingly, the olfactory context influenced thresholds for happiness and disgust. While in the pleasant context happiness was detected at lower intensities, the reverse bias was found for disgust with lower detection thresholds in the aversive context. These findings suggest that the emotional reaction induced by the odorants facilitates detection of expressions with the corresponding hedonic value. Therefore, functional coupling between its own emotions and those perceived in others may contribute to their accurate recognition, at least within an olfactory context.

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33.547 **Own-gender effects in post-adaptation changes to facial expression discrimination performance.** Jay Zhang[1](jayzhang@alumni.ubc.ca), Ipek Oruc[1]; [1]Department of Ophthalmology & Visual Science, Unviersity of British Columbia

We have previously shown that adapting to a specific identity improves discrimination of structural changes pertaining to identity on that face but not on other faces (Oruc & Barton, 2011). In this study we ask whether adapting to faces can improve discrimination of facial expression. 175 subjects participated (91 female). Each participant was randomly assigned to one of four test faces (two female) that remained constant throughout the session. We measured accuracy for perceiving subtle deviations in facial expression after adapting to expressive faces in five conditions: (1) same-identity/same-expression, (2) same-identity/different expression, (3) different-identity/same-expression, (4) different-identity/different expression, and (5) blank. Gender remained the same between test and adapting faces. Adapting stimuli were video clips displaying a progression from neutral to the full extent of the adapting expression. Adapting duration was 8s during which the same video clip repeated four times. The task was 2-interval 2-alternative forced choice discrimination of expression in which subjects viewed two static images each displaying a subtle deviation equidistant from a base expression towards two different end expressions. We hypothesized that performance in expression discrimination would improve after adapting to the same expression, but not a different expression, compared to baseline (blank). We also hypothesized that adaptation-induced improvements would be maximal when adapting faces had both the same identity and expression with the test faces. Results show an unexpected own-gender effect: adaptation facilitated discrimination accuracy for other-gender test faces (M=2.17%, $p<0.023$) but impaired it for own-gender faces (M=-3.15%, $p=0.002$) compared to baseline, also shown by a significant main effect of gender-congruency ($F(1, 684)=11.10$, $p<0.001$). There was no main effect or interaction involving adapting condition. Unlike the context of the own-race effect, observers should have equal exposure to male and female faces through their daily experience. This suggests a genetically determined component to facial expression processing.

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33.548 **Gender differences in the visual strategies underlying facial expression categorization** Caroline Blais[1](caroline.blais@uqo.ca), Daniel Fiset[1], Frédéric Gosselin[2]; [1]Département de Psychoéducation et de Psychologie, Université du Québec en Outaouais, [2]Département de Psychologie, Université de Montréal

Decoding facial expressions of emotions is a crucial ability for successful social interactions. Gender differences have been found in the neural responses to emotional faces (McClure et al., 2004), suggesting that men and women process facial expressions differently. The present study used the Bubbles technique (Gosselin & Schyns, 2001) to verify whether the visual strategies used in facial expression categorization (six basic emotions as well as neutral and pain expressions) differ across gender. 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 56% (halfway between chance and perfect performance) by adjusting the number of bubbles on a trial-by-trial basis using QUEST (Watson & Pelli, 1983). Thus, the number of bubbles reflected the participants' relative aptitude for this task. Forty-one participants (14 men) each categorized 4000 sparsed stimuli. On average, women performed better than men ($t(39) = 3.08$, $p<0.05$). Classification images showing which information in the stimuli correlated with participants' accuracy were constructed separately for each gender by performing a multiple linear regression on the bubbles' locations and accuracy. A pixel test was applied to the classification image to determine statistical significance (Zcrit = 3.36, $p<0.05$; corrected for multiple comparisons). Women used both eyes and mouth areas more efficiently than men. In order to verify if the visual strategy is modulated by gender when the ability to perform the task is factored out, we selected 12 men and women that were matched on the average number of bubbles (i.e., the 12 men (vs. women) with the highest (vs. lowest) performance), and we repeated the analysis described above. When performance was controlled for, women used the mouth area more than men, again suggesting that gender influences the visual strategy used for categorizing facial expressions.

33.549 **Show Me Your Poker Face: Are Poker Players Better at Recognizing Emotional Expressions?** Erin Browning[1](ebrowning@csu.fullerton.edu), Carol Huynh[2], Jessie Peissig [1]; [1]California State University Fullerton, [2]North Dakota State University

Two previous studies have found that paranoid schizophrenics are able to more accurately recognize genuine emotional expressions compared to both normal individuals and individuals diagnosed with other types of schizophrenia (LaRusso, 1978; Davis & Gibson, 2000). Additionally, paranoid schizophrenics more easily distinguish between genuine and posed expressions, whereas normal individuals typically label all expressions as genuine. Paranoid schizophrenics likely find it quite important to distinguish between "fake" and "real" emotions; this suggests that we might also find superior performance in other populations who would benefit from this skill. The purpose of this study was to use a database of genuine emotional expressions to evaluate the facial emotion recognition accuracy for poker players and non-poker players. It was hypothesized that face-to-face poker players should be better at recognizing subtle, genuine emotional expressions than non-poker players. Poker players who frequently play face-to-face poker were recruited from campus and a charity poker tournament. Non-poker players were recruited from campus. There were a total of 59 participants (15 campus poker players, 20 charity poker players, and 24 non-poker players). Participants were shown five different emotions (neutral, happy, disgust, fear, and sad) for eight different faces (4 male, 4 female). Surprisingly, we found no advantage in overall accuracy rates for poker players compared to non-poker players. In fact, the poker players were actually worse at recognizing emotions overall. A more detailed look at the data revealed that poker players recognized happy expressions significantly better than a non-poker player. These data suggest that rather than an overall increase in emotion recognition accuracy, poker players may instead develop superior performance for recognizing cues that someone has a "good hand." These results support the idea that it is possible to increase performance for recognizing emotions, and that sensitivity can be selectively heightened for only emotions that are task-relevant.

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Perceptual learning: Neural mechanisms

Sunday, May 12, 2:30 - 4:15 pm
Talk Session, Royal Ballroom 1-3
Moderator: Kazuhisa Shibata

34.11, *2:30 pm*

Experience-based development of internal probabilistic representations in the primary visual cortex József Fiser[1](fiser@brandeis.edu), Cristina Savin[2], Pietro Berkes[3], Chiayu Chiu[4], Máté Lengyel[2]; [1]Department of Cognitive Science, Central European University, Budapest, Hungary, [2]Computational & Biological Learning Lab, Department of Engineering, University of Cambridge, UK, [3]Volen National Center for Complex Systems, Brandeis University, [4]Department of Neurobiology, Yale University

The developmental increase in similarity between spontaneous (SA) and average stimulus-evoked activity (EA) in the primary visual cortex has been suggested to reflect a progressive adaptation of the animal's internal model to the statistics of the environment, a hallmark of probabilistic computation in the cortex (Berkes et al, 2011). Still, this gradual adaptation could be due to genetically controlled developmental processes that have little to do with the animal's visual experience. To clarify this issue, we disrupted normal visual experience of N=16 ferrets of different ages (P30-P120) so that the animals perceived only diffuse light through their eyelids up to the moment of data collection. We measured neural activity from the superficial layers of V1 and compared SA and EA to those in normally reared controls. Furthermore, we extended the original analysis using maximum entropy models that control not only for the effects of single unit firing rates, but also for the population firing rate distribution which could confound measures of functional connectivity that we use as a measure of learning. The general statistics of V1 activity in lid-sutured animals developed very similarly to controls confirming that withholding natural visual experience does not abolish the general development of the visual system. However, while in the control animals SA was completely similar to EA evoked by natural stimuli and significantly less similar to EA evoked by noise, in lid-sutured animals this specificity to natural inputs disappeared, and the match between SA and EA for natural inputs became incomplete. Our novel analysis further confirmed that learning drives the increase of similarity between SA and EA in the oldest control adults. These results suggest that while intrinsic development of visual circuitry is controlled by developmental factors, learning from visual experience is crucial for the emergence of a complete match between SA and EA.

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34.12, *2:45 pm*

No transfer from visual to visuomotor perceptual learning and vice versa Michael Herzog[1](michael.herzog@epfl.ch), Lukasz Grzeczkowski[1], Fred Mast[2]; [1]Laboratory of Psychophysics, Brain Mind Institute, Ecole Polytechique Fédérale de Lausanne (EPFL), Switzerland, [2]Department of Psychology, University of Bern, Switzerland

Perceptual learning is usually very specific. For example, performance improves when observers train with a vertical bisection stimulus. However, this improvement does not transfer to a horizontal bisection stimulus. Here, we show that perceptual learning is even specific for the response mode. Observers trained with vertical bisection stimuli comprising two outer and a central line. In the visuomotor learning condition, observers could adjust the center line by means of a computer mouse. Observers placed the center line in the middle between the two outer lines with a small displacement towards either the left or right outer line indicated by a cue randomly chosen. We asked observers to adjust the smallest displacement they could perceive. In the classical, visual learning condition, observers indicated by push button press if the center line was closer to the left or right outer line. Performance improved strongly in both conditions. However, improvements in either condition did not transfer to the other condition as shown by pre- and post-measurements, i.e., visuomotor learning did not improve visual performance and visual learning did not improve visuomotor performance. Hence, perceptual learning is specific to the response mode used during training- even though the visual stimuli are almost identical.

Acknowledgement: BMI-Hebrew Foundation

34.13, *3:00 pm*

Anodal tDCS to V1 blocks visual perceptual learning consolidation Megan A.K. Peters[3](meganakpeters@ucla.edu), Benjamin Thompson[2], Lotfi B. Merabet[4], Allan D. Wu[1], Ladan Shams[3]; [1]Department of Neurology, David Geffen School of Medicine, University of California, Los Angeles, [2]Department of Optometry and Vision Science, University of Auckland, Auckland, New Zealand, [3]Department of Psychology, University of California, Los Angeles, [4]Vision Rehabilitation Center, Department of Ophthalmology, Massachusetts Eye and Ear Infirmary, Harvard Medical School

Purpose and background. The purpose of this study was to examine the effects of visual cortex Transcranial Direct Current Stimulation (tDCS) on contrast sensitivity and consolidation of learning. Previous studies have demonstrated improvements in visual contrast sensitivity as a result of anodal tDCS, and decrements in sensitivity due to cathodal tDCS. Further, other studies have demonstrated polarity-specific effects of tDCS to motor cortices on consolidation of learned motor tasks. However, no studies have examined effects of tDCS on overnight consolidation of visual perceptual learning. Methods. Over two consecutive days, twenty-four healthy participants performed a contrast detection task. Each day included two sessions: a baseline measurement followed by measurements made during tDCS stimulation (active or sham). Participants were separated into three groups of eight participants each. One group received anodal stimulation to primary visual cortex (V1) on the first day, while another received cathodal stimulation; stimulation polarity was reversed for these groups on the second day. The third group received sham stimulation on both days. Results. We observed no improvements or decrements in contrast sensitivity relative to the same-day baseline during real tDCS, nor were there any measurable within-session learning trends. However, participants in the groups that received either cathodal or sham tDCS on Day 1 demonstrated significantly improved task performance on Day 2, while no such improvement was found for the participants who received anodal stimulation on Day 1. Discussion and conclusions. These results indicate that anodal tDCS blocked overnight consolidation of visual learning; possible mechanisms for this blocking include engagement of inhibitory homeostatic plasticity mechanisms, or alteration of the signal-to-noise ratio within stimulated cortex. To our knowledge this is the first study to demonstrate the effects of tDCS on consolidation of learning within the visual cortex.

34.14, *3:15 pm*

Improving visual cognition through stroboscopic training Lawrence Appelbaum[1,2](greg@duke.edu), Matthew Cain[3], Julia Schroeder[4], Elise Darling[5], Stephen Mitroff[5]; [1]Psychiatry and Behavioral Sciences, Duke University, [2]Center for Cognitive Neuroscience, Duke University, [3]Department of Cognitive Linguistic & Psychological Sciences, Brown University, [4]Department of Psychology, University of California, [5]Department of Psychology and Neuroscience, Duke University

If people are forced to operate in an impoverished visual environment, might their visual abilities improve once they return to a normal environment? In a set of four experiments we tested this question by determining whether athletic training under stroboscopic visual conditions has the capacity to improve visual perception and cognition. In each experiment, participants were assigned to either an experimental condition wherein they trained with stroboscopic eyewear or to a control condition in which they underwent identical training with non-stroboscopic eyewear. The training consisted of multiple sessions over a number of days during which participants performed athletic drills such as throwing and catching. To determine if training led to generalizable benefits, we used computerized measures to assess perceptual and cognitive abilities on a variety of tasks before and after training. Computer-based assessments included measures of visual sensitivity (central and peripheral motion coherence thresholds), transient spatial attention (a useful field of view – dual task paradigm), sustained attention (multiple-object tracking), and visual memory (partial report task). In all tasks re-test performance was measured immediately after training, and for a subset of the tasks additional participants were re-tested with a 24-hour delay after training to assess retention. Results revealed that stroboscopic training led to significantly greater re-test improvement compared to the control group in central visual field motion sensitivity and transient attention abilities. In addition, stroboscopic training led to enhancements in short-term visual memory capacity, and these trained improvements were maintained for at

least 24-hours. No significant training benefits were observed for peripheral motion sensitivity or peripheral transient attention abilities, nor were benefits seen for sustained attention during multiple-object tracking. These findings demonstrate that stroboscopic training can effectively improve some, but not all, aspects of visual cognition and suggest a potentially powerful tool for performance enhancement and/or remediation.

34.15, *3:30 pm*

Perceptual learning is associated with different types of plasticity at different stages – revealed by fMRI Kazuhisa Shibata[1,2](kazuhisa_shibata@brown.edu), Yuka Sasaki[1,2], Mitsuo Kawato[2], Takeo Watanabe[1,2]; [1]Department of Cognitive, Linguistic & Psychological Sciences, Brown University, [2]ATR Brain Information Communication Research Laboratory Group

Visual perceptual learning (VPL) is long-term visual performance improvement after visual experiences. Which stage of visual processing is changed in association with VPL is one of the most serious controversies in the field. The low-level model of VPL attributes VPL to changes only in visual areas. The higher-level cognitive model attributes VPL to changes in decision-related areas or in connectivity between visual and decision-related areas. Here we show the evidence that supports a two-stage model in which VPL is associated with the changes in both visual and decision-related areas that reflect different aspects of plasticity. Thirteen human subjects participated in a 10-day training on a global motion detection task for a certain motion direction (trained direction). After training, the subjects' performance significantly improved specifically for the trained direction, but not for an untrained direction. Before and after training, we measured subjects' functional magnetic resonance imaging (fMRI) signals in relevant motion condition and irrelevant motion condition. In the relevant motion condition, the subjects engaged in the same task as in training. In the irrelevant motion condition, the subjects were asked to perform a letter detection task while the same motion stimulus as in the training was presented in the background as task-irrelevant. A pattern-classification analysis revealed that visual area V3A, which has been implicated in VPL of global motion in some studies, showed significant response changes to the trained motion direction in both conditions. On the other hand, intraparietal sulcus (IPS), which is regarded as decision-related and has also been implicated in VPL of motion in other studies, showed significant response changes to the trained direction only in the relevant motion condition. These results indicate that VPL of global motion results from two different types of plasticity at different stages, feature-specific plasticity and task-specific plasticity, and may resolve the long-standing controversy.

Acknowledgement: This study is supported by Japanese MEXT SRPBS, NIH R01 EY015980, and NIH R01 EY019466.

34.16, *3:45 pm*

How to make a grandmother cell using Spike-Time Dependent Plasticity (STDP) Simon Thorpe[1](simon.thorpe@cerco.ups-tlse.fr), Olivier Bichler[2]; [1]CerCo, Université Toulouse 3, CNRS, Toulouse, France, [2]CEA LIST&LETI - NanoComputing, Gif sur Yvette, France

In a recent study, we demonstrated that a simple two-layer network of spiking neurons equipped with a novel Spike-Time Dependent Plasticity rule was capable of spontaneously learning to detect complex dynamic visual stimuli (Bichler et al, 2012, Neural Networks, 32, 330-48). The network received spike-like events from a Dynamic Vision Sensor chip that asynchronously generates "ON" and "OFF" spiking events in response to changes in luminance. After a few minutes of stimulation corresponding to the passage of cars on a 6-lane freeway, we found that the 60 neurons in the first layer had formed receptive fields that correspond to car-like shapes at particular locations on the road, whereas the 10 neurons in the second layer had learned to "count" cars going by on each of the six lanes. Importantly, this sort of learning was entirely unsupervised and reflected the fact that the STDP leads neurons to become selective to spatio-temporal spike patterns that occurred repeatedly. In general, a few tens of repetitions are enough for the selectivity to develop. In the current study, we demonstrated that this sort of learning could effectively lead to the development of "grandmother cell" coding. For example, a neuron that initially responded to continuous random synaptic inputs at roughly 2 spikes/second could be trained to respond selectively to a specific repeating sequence after only a few tens of repetitions. The remarkable finding is that when we returned to the original random input pattern, the neuron was now completely silent and would remain silent indefinitely. However, if ever the pattern used during training is presented again, even after a very long delay, the neuron would immediately respond at a short latency. We propose that this simple mechanism could underlie the ability of the brain to store long-term sensory memories.

Acknowledgement: ANR-NEMESIS

34.17, *4:00 pm*

Retinotopy of the cortical lesion projection zone in macular degeneration Koen V. Haak[1,2,3](haak@umn.edu), Antony B. Morland[3,4], Frans W. Cornelissen[2]; [1]Department of Psychology, University of Minnesota, [2]Laboratory for Experimental Ophthalmology, University Medical Center Groningen, University of Groningen, [3]York Neuroimaging Centre, Department of Psychology, University of York, [4]Centre for Neuroscience, Hull-York Medical School, University of York

Macular degeneration (MD) causes lesions to the center of the retina. There is no cure for MD but several promising treatments aimed at restoring retinal lesions are under investigation. These restorative treatments, however, rely on the assumption that the patient's brain can still process the retinal signals once they are restored. Whether this assumption is correct has yet to be determined. In previous work, we already established that the early visual cortex in MD does not reallocate its resources to processing the intact peripheral visual field (Baseler et al. 2011, Nature Neuroscience 14: 649-655), but it is still possible that long-term visual deprivation leads to visual cortical degeneration (Boucard et al. 2009, Brain 132: 1898-1906). Here, we used functional magnetic resonance imaging (fMRI) and a new fMRI data-analysis tool – connective field modeling (Haak et al. 2012, NeuroImage 66: 376-384) – to evaluate the retinotopic organization of the cortical lesion projection zone (LPZ) in 8 MD patients and 12 age-matched controls with simulated retinal lesions. We found that the functional connectivity between the sensory-deprived parts of visual areas V1 and V2 is still retinotopically organized in the patients with MD, although less so than in the controls with simulated retinal lesions. Moreover, the decreased retinotopic functional connectivity in MD correlated strongly with fixation instability, and not with the size of the retinal lesion, suggesting that the difference between MD patients and controls is mainly an artifact of poor fixation. Thus, it appears that the retinotopic configuration of the LPZ remains largely intact, despite the prolonged loss of visual input due to MD. These results are reassuring, because they suggest that the restoration of sight in MD can probably rely on the visual cortex maintaining a largely unchanged mapping of the visual field.

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3D Perception

Sunday, May 12, 2:30 - 4:15 pm

Talk Session, Royal Ballroom 4-5

Moderator: Jenny Read

34.21, *2:30 pm*

Pupil shape is adaptive for many species. William Sprague[1](bill.sprague@berkeley.edu), Zachary Helft[1], Jared Parnell[2], Jurgen Schmoll[2], Gordon Love[2], Martin Banks[1]; [1]School of Optometry, Vision Science Program, University of California, Berkeley, [2]Department of Physics, Durham University

Pupil shape varies considerably across species, though most are circular or elliptical. Elliptical pupils are always elongated vertically or horizontally relative to the head. We examined the usefulness of elongated pupils: specifically, why horizontal elongation is useful to some species and vertical elongation to others. Walls (1942) proposed that such pupils are adaptive for nocturnality, providing more control over retinal illumination. Malmström and Kröger (2006) proposed that they preserve image quality in eyes with multifocal lenses. However, these proposals do not explain why pupil orientation varies across species. We propose a new theory based on the visual requirements of different species in their environments. We examined pupil shape in over 200 animals and related it to activity time, foraging mode, and height. Clear correlations emerged. Round pupils occur in tall or diurnal predators. Vertical elongation occurs in short, nocturnal predators; these animals usually have forward-facing eyes and stereovision. Horizontally elongated pupils occur in prey animals; they tend to have lateral eyes. We argue that vertical pupils are well suited for using stereopsis to estimate distances of vertical contours and using depth-of-field blur for distances of horizontal contours. In an analysis of image formation, we found that the potential usefulness of blur is inversely related to height. This may explain why vertical-slit pupils are more common in short than tall predators. For horizontally elongated pupils, our optical analyses show that the elongation expands field of view horizontally allowing these terrestrial prey animals to see objects near the ground plane both in front of and behind them. Our analyses also show that horizontal elongation allows sharper imaging of

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horizontal contours on the ground in different directions, particularly directions well off the optic axis. We conclude that elongated pupils evolved to optimize visual information near the ground plane in predators and prey.

34.22, *2:45 pm*

Neuronal selectivity for directions of 3D motion in area MT Thaddeus Czuba[1](czuba@utexas.edu), Lawrence Cormack[3], Alexander Huk[2,3], Adam Kohn[1]; [1]Dept. of Neuroscience, Albert Einstein College of Medicine, [2]Section of Neurobiology, The University of Texas at Austin, [3]Center for Perceptual Systems, Dept. of Psychology, & Institute for Neuroscience, The University of Texas at Austin

The mechanisms of frontoparallel (2D) motion processing have been studied extensively and are relatively well understood. However, it remains unclear how the visual system encodes motion that includes a component toward or away from the observer (3D motion). Traditional accounts suggest that binocular 3D motion processing relies on changes in disparity over time, but recent work argues that in many situations the most relevant cue might be interocular velocity differences (IOVD): differences in horizontal velocity signals in the two eyes that are geometrically coincident with changes in disparity over time (Cumming & Parker, 1994; Czuba et al., 2010; Shioiri et al., 2000). We tested how the motion processing pathway encodes binocular 3D motion information by performing extracellular recordings in area MT of anesthetized macaques. We measured responses to a full matrix of monocular and binocular motion conditions using drifting sinusoidal gratings, varying absolute and relative temporal frequencies in the two eyes so that binocular conditions spanned a broad range of 3D motion trajectories. Many MT cells showed similar preferences for monocular motion in each eye and straightforward summation of these signals for binocular stimuli—these cells did not encode IOVD information. However, an interesting subset of cells exhibited robust IOVD information, evident either as opposite direction preferences for motion shown in each eye or strong nonlinear interactions for binocular motion. We also performed detailed measurements of disparity selectivity, and found cells selective for 3D directions of motion could be either sensitive or insensitive to static disparities. Together, our results suggest area MT contains robust signals for 3D motion processing through IOVD sensitivity. Our data also provide a promising framework for exploring how 2D and 3D directions of motion could be represented by a common population of neurons along known—classically 2D—motion pathways.

Acknowledgement: NEI R01-EY020592

34.23, *3:00 pm*

Grouping Disrupts Depth Magnitude Percepts from Stereopsis

Lesley Deas[1](ldeas@yorku.ca), Matthew Cutone[1], Laurie M. Wilcox[1]; [1]Department of Psychology, Centre for Vision Research, York University

Discrimination thresholds for a pair of vertical lines are typically very precise, but increase dramatically when these lines are connected to form a closed figure (McKee, 1983, Vision Research, 23, 191-198). Here we explore the possibility that degradation in performance reflects depth averaging, brought about by mid-level grouping operations. To this end, we assess suprathreshold depth magnitude percepts for a set of stimuli which provide consistent local disparity information, while their interpretation as part of an object is manipulated. We presented four equally spaced vertical lines and observers judged the relative depth of the central pair in three conditions: (i) isolated lines, (ii) within an object (connecting central pair with horizontal lines), and (iii) between two objects (connecting central lines with outer lines). We used a precisely calibrated pressure-sensitive sensor to record the perceived depth separation of the central lines. In a second experiment, we evaluated the impact of conflicting perspective on the strength of the effect. Our results show a strong and consistent reduction in the relative depth estimated within an object relative to the isolated line condition. Further, this loss of depth magnitude is eliminated in the between object condition, and estimates return to the levels found for isolated lines. Manipulation of perspective cues did not affect this pattern of results. Taken together, our results show that figural grouping is a strong determinant of the amount of depth perceived in simple stimuli. These findings extend existing research that has shown threshold performance to be susceptible to configuration. However the extension of this influence to suprathreshold estimates of depth magnitude is notable, and suggests that within-object disparities are subject to a form of depth averaging that enhances their perceived cohesiveness. When these identical components form the edges of separate objects, this averaging does not occur, thus promoting object segregation.

Acknowledgement: Ontario Trillium Foundation Natural Sciences and Engineering Research Council of Canada

34.24, *3:15 pm*

Luminance-disparity interaction in edge localization Alan Robinson[1,2](robinson@cogsci.ucsd.edu), Stuart Anstis[1], Donald MacLeod[1]; [1]Psychology Department, UC San Diego, [2]Cognitive Science Department, UC San Diego

Depth perception relies on many cues, with disparity being perhaps the most compelling. Our spatial resolution limit for disparity, however, is only ~4cpd. This low pass characteristic suggests that disparity transitions should appear blurry: a near object against a far background should appear to warp toward the background around the edges, due to the loss of high spatial frequencies; just as blurring a luminance pattern creates intermediate values between light and dark transitions. Since this does not occur, we propose that disparity perception is modulated by other features perceivable at a higher spatial resolution. Here we show luminance, which has a much higher spatial resolution, is combined with disparity to determine the locations of edges. Three subjects judged the locations of depth defined OR luminance defined edges, which were shown at the same time with varying amounts of spatial separation on a mirror stereoscope. Although subjects were instructed to ignore the task-irrelevant edge in each condition, they could not. Even when the two edges could be perceptually distinguished, judgments about the depth edge's location were shifted toward the luminance edge. Judgments about the luminance edge were also shifted toward the depth edge, but to a smaller amount. For both judgments, we found that reducing the visibility of the disparity defined edge caused the luminance defined edge to have a greater influence. Thus our data are roughly compatible with optimal cue combination models that give more reliable cues a heavier weight. All cues (depth and luminance) contribute to the final percept, with an adaptive weighting depending on the task and the acuity with which that cue is perceived. Since luminance acuity is generally higher than disparity acuity, however, we conclude that most often luminance edges will serve to define the edges of objects, not disparity.

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34.25, *3:30 pm*

Predicting the effects of illumination in shape from shading Roland Fleming[1](roland.w.fleming@psychol.uni-giessen.de), Romain Vergne[1,2], Steven Zucker[3]; [1]Experimental Psychology, University of Giessen, Germany, [2]Maverick, INRIA Grenoble-Rhône-Alpes and LJK (University of Grenoble and CNRS), France, [3]Computer Science, Yale University, New Haven, CT

Shading depends on different interactions between surface geometry and lighting. Under collimated illumination, shading is dominated by the 'direct' term, in which image intensities vary with the angle between surface normals and light sources. Diffuse illumination, by contrast, is dominated by 'vignetting effects' in which image intensities vary with the degree of self-occlusion (the proportion of incoming direction that each surface point 'sees'). These two types of shading thus lead to very different intensity patterns, which raises the question of whether shading inferences are based directly on image intensities. We show here that the visual system uses 2D orientation signals ('orientation fields') to estimate shape, rather than raw image intensities and an estimate of the illuminant. We rendered objects under varying illumination directions designed to maximize the effects of illumination on the image. We then passed these images through monotonic, non-linear intensity transfer functions to decouple luminance information from orientation information, thereby placing the two signals in conflict. In Task 1 subjects adjusted the 3D shape of match objects to report the illusory effects of changes of illumination direction on perceived shape. In Task 2 subjects reported which of a pair of points on the surface appeared nearer in depth. They also reported perceived illumination directions for all stimuli. We find that the substantial misperceptions of shape are well predicted by orientation fields, and poorly predicted by luminance-based shape from shading. For the untransformed images illumination could be estimated accurately, but not for the transformed images. Thus shape perception was, for these examples, independent of the ability to estimate the lighting. Together these findings support neurophysiological estimates of shape from the responses of orientation selective cell populations, irrespective of the illumination conditions.

Acknowledgement: NSF-BMBF Joint Program in Computational Neuroscience (FKZ: 01GQ1111)

34.26, *3:45 pm* **Is stereopsis optimized for our natural environment?**

Emily A. Cooper[1](emilycooper@berkeley.edu), William W. Sprague[2], Ivana Toši⊠[3], Martin S. Banks[2]; [1]Helen Wills Neuroscience Institute, University of California, Berkeley, [2]School of Optometry, Vision Science Program, University of California, Berkeley, [3]Ricoh Innovations, Inc.

Sunday PM

We asked if regularities in the visual environment provide a basis for some unexplained phenomena in stereovision. Specifically, we asked whether the positions of corresponding retinal points—positions in the two eyes that when stimulated yield the same perceived direction—are adapted to regularities in the binocular disparities encountered in the everyday environment. The positions of objects in the world that stimulate corresponding points define the horopter. Stereopsis is most precise near the horopter, which is pitched top back above fixation and is curved somewhat convexly to the left and right of fixation. Does the horopter align with regularities in the 3D visual environment? To answer this, we built a mobile device that simultaneously measures binocular fixations and the 3D scene layout. Subjects performed everyday activities, like preparing a meal or walking through an environment, while we measured where they were looking (including how far away) and the 3D scene in front of them. From these data we reconstructed the images projected to the eyes, particularly the binocular disparities, as subjects performed these tasks. The data revealed a number of things. 1) Disparities encountered during everyday tasks have clear regularities, which vary across tasks. 2) The encountered disparities tend to be uncrossed above fixation and crossed below in agreement with the pitch of the vertical horopter. 3) The encountered disparities during some, but not all, tasks tend to be uncrossed to the left and right of fixation in agreement with the convexity of the horizontal horopter. Thus, despite varying patterns from one task to another, the disparity distributions we measured generally align with the positions of corresponding points, supporting the hypothesis that the regions of best stereovision are well adapted to the complex patterns of visual input experienced in everyday activities.

34.27, *4:00 pm*

Pictorial depth is not statistically optimal Dhanraj Vishwanath[1](dv10@st-andrews.ac.uk), Fulvio Domini[2,3]; [1]School of Psychology and Neuroscience, University of St. Andrews, [2]Cognitive, Linguistic & Perceptual Sciences, Brown University, [3]Italian Institute of Technology

The visual system is conventionally assumed to be optimized for recovering the 'veridical' structure of the external 3D world. A major paradox for this view is the perception of pictorial depth. Pictures generate a robust impression of depth and 3D structure contrary to physical reality. This paradox is often overlooked because it is conventionally assumed that pictorial depth is the statistically optimal outcome of a computation involving conflicting independent depth signals. Surprisingly, this assumption has never been tested. Here we examined if the perception of depth in pictorial images can be explained by any of the variants of statistically optimal cue combination (maximum likelihood estimation (MLE), statistical robustness, cue promotion, etc.). Methods: Subjects viewed simple pictures consisting of a textured elliptical hemi-cylinder and judged the perceived curvature-in-depth. We measured both the magnitude of perceived depth (PSEs) as well as thresholds (JNDs) for depth discrimination under binocular and monocular viewing for different base curvatures. We also measured depth discrimination thresholds for disparity specifying a flat surface. Results: There was a predicted effect of base curvature on depth magnitude judgments, but surprisingly no difference between monocular and binocular viewing for any base curvature. Disparity thresholds were an order of magnitude lower than those for texture. These results are contrary to MLE which predicts that disparity should have received a much higher weight than texture, yielding smaller depth magnitudes under binocular viewing (especially at low curvatures). Statistical robustness also predicts little or no depth under binocular viewing, since disparity (and not texture) is consistent with other potentially available cues, all of which specify a flat surface (visible surface microtexture, sequential vergence, defocus blur, motion parallax from small movements). Invoking other popular statistical free parameters such as the "flatness prior" makes the situation worse. We discuss the results in the context of alternative theories of depth cue combination based on signal-to-noise ratios.

Multisensory processing

Sunday, May 12, 5:15 - 7:00 pm

Talk Session, Royal Ballroom 1-3

Moderator: David Burr

35.11, *5:15 pm*

Blindness produces yoked changes in V1 cortical thickness, cross-modal responses, and resting metabolism. Ritobrato Datta[1](ridatta@mail.med.upenn.edu), Aleksandra B. Daina[1], Lauren Brandes[1], Efstathios D. Gennatas[2], Sashank Prasad[1], Omar H. Butt[1], Geoffrey K. Aguirre[1]; [1]Department of Neurology, University of Pennsylvania, Philadelphia 19104, [2]Department of Psychiatry, University of Pennsylvania, Philadelphia 19104

Blindness alters brain structure and function, but whether these specific changes are related or independent across subjects has not been examined. We tested the hypothesis that blind individuals with thickened striate cortex (indicative of altered synaptic pruning) would show linked changes in cross-modal neural response and resting blood flow. 37 blind (55±12 years) and 23 sighted (38±17) participants were studied. fMRI data were collected at rest in darkness and during a semantic decision task (plausibility judgement of spoken sentences). MPRAGE, resting perfusion and DTI were also acquired. Mean cerebral blood flow (CBF), cross-modal activation to auditory sentences (BOLD %), cortical thickness, and surface area were measured within V1. Functional connectivity between V1 and somatosensory and Broca's area were calculated from rest data. Volumes and fractional anisotropy (FA) of the optic and radiations, pericalcarine white matter, and splenium were obtained. We replicated prior work, finding significant differences between the sighted and blind groups in almost every measure. We then examined if there exist correlations across blind subjects in structural and functional alterations which may not be present in the sighted group. Cortical thickness was significantly correlated (and V1 surface area negatively correlated) with cross-modal activation (r=0.51), which in turn was strongly correlated with V1 perfusion at rest (r=0.47) and long-range functional connectivity with somatosensory cortex (r=0.63). Interestingly, anatomical measures of the anterior visual pathway (chiasmal volume and FA, optic radiation FA) were not correlated with these alterations. Our results provide a direct link between presumed alterations in cortical maturation in blindness that lead in turn to preserved long-range functional connections, and cross-modal representation. Further, these "compensatory" changes appear to be independent from the "degeneration" changes in the anterior visual pathway associated with damage to the neural retina.

Acknowledgement: R01 EY020516-01A1

35.12, *5:30 pm*

Reorganization of auditory motion direction encoding in early blind humans Fang Jiang[1](fjiang@u.washington.edu), G.C. Stecker[2], Ione Fine [1]; [1]Department of Psychology, University of Washington, [2]Speech & Hearing Science, University of Washington

Studies showing that occipital cortex responds to auditory and tactile stimuli after early blindness are often interpreted as demonstrating that early blind subjects 'see' auditory and tactile stimuli. One such example is that area hMT+ - a region associated with visual motion processing in sighted – responds to auditory and tactile motion stimuli within early blind individuals. However, to claim that blind subjects 'see' using occipital cortex requires that occipital responses directly mediate the perception of auditory stimuli, rather than simply modulating or augmenting responses within auditory areas. To identify regions associated with the conscious experience of auditory motion we dissociated neuronal responses associated with the perceptual experience of motion from the physical presence of motion in the display by asking observers to report the perceived direction of an ambiguous stimulus. Both coherent and ambiguous motion stimuli were defined using a combination of inter-aural time differences, inter-aural level differences, and Doppler shift that simulated an auditory stimulus traveling along a fronto-parallel plane. No net motion was applied in the ambiguous motion stimulus. Using fMRI pattern classification, we found that in sighted individuals the perceived direction of motion for both coherent and ambiguous auditory motion stimuli was accurately categorized based on neural responses within auditory cortex (specifically the right planum temporale and lateral occipital cortex). In contrast, 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 either the planum temporale or lateral occipital cortex. This double dissociation demonstrates first that early blind responses to auditory motion within MT+ are associated with the perception of auditory motion, and second that these responses do indeed supplant rather than augment the role of auditory cortex in auditory motion perception. Blind individuals do indeed 'see' auditory motion.

Acknowledgement: NIH EY-014645

35.13, *5:45 pm*

The face and voice of multisensory integration: prior knowledge affects multisensory integration from early childhood Karin Petrini[1](k.petrini@ucl.ac.uk), Georgina Denis[2], Scott Love[3], Marko Nardini[1]; [1]Department of

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Visual Neuroscience, UCL Institute of Ophthalmology, London, UK, [2]UCL Institute of Neurology, London, UK , [3]Department of Psychological and Brain Sciences, Indiana University Bloomington

To reduce sensory uncertainty and reach a decision, the brain can use sensory combination and acquired knowledge. Whereas adults can reduce uncertainty by combining sensory estimates, in recent studies children below 8 years failed to do so. Here we ask whether children's multisensory processing is sensitive to prior knowledge about cue correspondences. Fifteen adults, thirteen 10-11, and fourteen 7-8 year-old children gave simultaneity judgments (SJ) and temporal order judgments (TOJ) for audiovisual displays with varying degrees of synchrony. We compared stimuli in which prior knowledge predicts a low (beep-flash) vs. a high (face-voice) degree of audiovisual correlation. Psychometric functions were fitted to proportions of 'simultaneous' (SJ task) and 'vision first' (TOJ task) responses in order to measure observers' temporal integration windows (TIWs) across tasks and stimuli. We interpret a larger TIW in the TOJ compared with the SJ task as indicating mandatory integration of estimates, as reflected in an impaired ability to judge which came first (despite an ability, in the SJ task, to judge whether they were simultaneous −Hirsh, 1961). Overall, TIWs reduced with age: children were less sensitive than adults to audiovisual asynchrony. Differences in the size of TIW for SJ vs. TOJ tasks also significantly decreased with age, indicating that children were more subject than adults to mandatory integration of estimates. Across ages, the TOJ-SJ difference was greater for face-voice than flash-beep stimuli, showing that children, like adults, were affected by prior knowledge about cue correspondences. Finally, correlation analyses revealed that children's sensitivity to audiovisual asynchrony across the two tasks was correlated, while, in line with previous findings, the sensitivity of adults was not (van Eijk, Kohlrausch, Juola, van De Par, 2008). Together these results indicate that while prior knowledge affects multisensory integration from early childhood, with age more specific task-related multisensory mechanisms emerge.

Acknowledgement: Supported by the James S. McDonnell Foundation 21st Century Science Scholar in Understanding Human Cognition Program

35.14, *6:00 pm*

Changing pitch modulates motion-direction information in V1 Won Mok Shim[1](Won.Mok.Shim@dartmouth.edu), Stefan Uddenberg[1], Yune-Sang Lee[2]; [1]Psychological and Brain Sciences, Dartmouth College, [2]Center for Cognitive Neuroscience, University of Pennsylvania

Although the sight and sound of objects were thought to be encoded initially via separate visual and auditory pathways, then combined later in high-level multisensory areas, there is growing evidence that multisensory processing also occurs in early modality-specific sensory cortices. However, it remains unclear how uni-modal sensory information in the early sensory cortex is influenced by information from other senses when the association between information from different modalities is abstract in nature, without natural spatiotemporal correspondence. In order to address this question, using fMRI and multi-voxel pattern analysis, we examine whether motion direction information in V1 is modulated when a moving stimulus is presented with a changing pitch that is congruent or incongruent with respect to the direction of visual motion. Random dots moving either upward or downward in a circular annulus were presented with an ascending or descending pitch. While fixating at the center, subjects monitored random dots for occasional changes in their motion direction. The motion direction of random dots was successfully decoded in V1 when the direction of visual motion and changing pitch were congruent (e.g., ascending pitch and upward motion or descending pitch and downward motion), but decoding accuracy significantly decreased when they were incongruent. These findings suggest that visual motion information in the early visual cortex is modulated by concurrently present auditory information, even when their association is only "metaphoric."

35.15, *6:15 pm*

Evidence for an abstract multi-modal sense of number David Burr[1-3](dave@in.cnr.it), Irene Togoli[1], Roberto Arrighi[1]; [1]Department of Neuroscience, University of Florence, Italy, [2]CNR Institute of Neuroscience, Pisa, Italy, [3]School of Psychology, University of Western Australia

A truly abstract number sense should be capable of encoding the numerosity of any set of discrete elements, whether events or objects, simultaneous or sequential, from any sensory modality. Recently we have shown that like other visual attributes, visual numerosity is susceptible to adaptation (Burr and Ross, 2008, Curr. Biol.). We now demonstrate that adaptation also occurs with sequentially presented items, across modalities and across formats (sequential vs simultaneous). Adapting to a series of flashes presented at 2, 4 or 8 Hz for about 40 seconds changes the perceived numerosity of visual pulses (range 2-20) presented within a temporal window of 2 seconds: adapting to 2 Hz increased perceived number by 15-20%; adapting to 8 Hz decreased perceived number by a similar amount; and 4 Hz adaptors had no effect. For adaptation to occur, the adaptor stimulus had to occupy the same spatial position as the test: they need to coincide on the screen, but not on the retina, implying spatiotopic selectivity. Similar adaptation effects were observed for auditory stimuli (adaptation to tone sequences), and also cross-modally: adapting to auditory bursts affected perceived visual numerosity and vice versa, to the same extent as intra-modal adaption. Finally we demonstrated cross-format adaptation: adapting to sequential streams of flashes reduced the perceived numerosity of spatial arrays. All these results point to the existence of a perceptual system that transcends vision and audition to encode an abstract sense of number, in space and in time. This multi-sensory, multi-dimensional mechanism is clearly separate from other perceptual systems, such as those encoding texture or density.

Acknowledgement: European Research Council: 229445 Australian Research Council: DP0879010

35.16, *6:30 pm*

Are synesthetes different beyond their synesthetic associations?
Charlotte Chun[1,2](charlottechun@fulbrightmail.org), Jean-Michel Hupe[1]; [1]Centre de Recherche Cerveau et Cognition, Université de Toulouse & Centre National de la Recherche Scientifique, 31300 Toulouse, France., [2]P.O. Box 26170. University of North Carolina at Greensboro. Greensboro, NC, 27402-6170

Synesthesia, a subjective phenomenon in which individuals experience an automatic connection between two or more senses, is purportedly associated with other personal characteristics, like mental imagery, personality and creativity. The visual and linguistic predominance of the majority of types of synesthesia suggest that synesthetes may differ along these dimensions. We compared cognition, personality factors, visual mental imagery, and creative thinking in groups of synesthetes and non-synesthetes. Participants were recruited from universities and public museums (n=3743) to complete an online screening survey, thus avoiding the typical recruitment bias wherein synesthetes spontaneously contact researchers. From the initial pool of respondents (n=1092), we selected a group of verified synesthetes (n=29) and non-synesthetes (n=36) to complete tests of global cognition and creative thinking (verbal, visual, convergent, and divergent), as well as questionnaires of personality and mental imagery. Synesthetes showed enhanced verbal comprehension (WAIS-III index), elevated self-reports of openness to experience and absorption in imaginative activities on personality questionnaires, as well as slightly higher usage (but not vividness) of visual mental imagery. They also scored higher on visual convergent and verbal divergent thinking tests. We evaluated the overall strength of these differences with linear discriminant classification analysis and a leave-one-out procedure. Using all cognitive and personality scores, the classifier correctly predicted whether a subject was a synesthete or not in 67% of the cases (p=0.06, randomization test). In comparison, the same classifier performed at 76% when differentiating men and women. Performance for synesthesia reached 70% (p=0.02) on the basis of the four creativity tests. If, as a group, synesthetes differ from the general population, these differences are still less pronounced than those observed here between men and women (that is, within French culture), suggesting that on an individual level, synesthetes may not necessarily show exceptional characteristics beyond their phenomenal synesthetic experiences.

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35.17, *6:45 pm*

Neural correlates of time marker for simultaneity judgment Kaoru Amano[1,2](amano@brain.k.u-tokyo.ac.jp), Liang Qi[1], Tsunehiro Takeda[1], Shin'ya Nishida[3]; [1]Graduate School of Frontier Sciences, The University of Tokyo, [2]PRESTO, JST, [3]NTT Communication Science Laboratories

Whereas sensory processing latency is altered by many factors including stimulus intensity and processing channel, the simultaneity judgment between two sensory signals is generally much more accurate (i.e., more consistent with the original event timings) than predicted from response latencies to those signals. This suggests that apparent simultaneity is based on the "time markers" of the input signals, which are different from the timings of signal detection in the brain. The neural correlate of time marker however remains unknown. Here we measured brain activity with magnetoencephalography (MEG) while the subjects performed one of two tasks. In the simple reaction time (RT) task, subjects responded to an onset of random-dots coherent motion. In the synchrony judgment task, they judged simultaneity between coherent motion onset and a beep sound for several SOAs. For both tasks, coherence of random-dots motion

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changed abruptly from 0% to 30, 40 or 90% (step) or gradually from 0% to 90% at the rate of 80, 120 and 200 %/s (ramp). We found that motion coherence affected RT and the point of subjective simultaneity (PSS) differently. For the step stimuli, increasing motion coherence decreased RT but had no effect on PSS. For the ramp stimuli, on the other hand, motion coherence affected not only RT but also PSS. These modulations of RT and PSS could be predicted by the timing when leaky-integrated hMT+ response crossed certain thresholds. The threshold for PSS was smaller than that for RT, indicating that the time marker for simultaneity judgment is located at the timing earlier than the detection latency. We suggest that synchronous perception is based on a comparison of the time marker assigned at the timing when leaky-integrated sensory response crossed a relatively low threshold. This time marker is considerably independent of stimulus amplitude, and thus contributes to accurate timing perception.

Spatial vision: Crowding, texture

Sunday, May 12, 5:15 - 7:15 pm

Talk Session, Royal Ballroom 4-5

Moderator: Hakwan Lau

35.21, *5:15 pm*

Inflation of subjective perception in peripheral vision Guillermo Solovey[1](gs2648@columbia.edu), Brian Maniscalco[1], Dobromir Rahnev[2], Hakwan Lau[1]; [1]Department of Psychology, Columbia University (NYC), [2]Department of Psychology, University of California at Berkeley

There is a compelling subjective impression that peripheral vision is colorful and vivid. However, peripheral visual processes carry less information than foveal vision: it is associated with low spatial resolution, low color sensitivity and in general receives little attention compared to the foveal location. How does this low information capacity account for the subjective vividness in peripheral perception We have previously shown that at identical eccentricity, the lack of covert spatial attention can inflate subjective perception, making detection criterion liberal (Rahnev et al 2011 Nature Neuroscience). Our computational model suggests that this is because under the lack of attention, the internal perceptual response may be more variable. Under a somewhat inflexible detection criterion set commonly for both the attended and unattended locations, high variability may mean that the internal response can exceed the criterion more frequently, leading to a liberal detection bias. We hypothesized that the same mechanism of subjective perceptual inflation may be at work in peripheral vision. We investigated this possibility in psychophysical experiments in which subjects detected the presence of Gabor patches in either the fovea or the periphery. Confirming our hypothesis, we found that subjects tended to use a more liberal detection criterion in the periphery than in the center (that is, subjects reported seeing the target more frequently in the periphery). In trying to understand the neurobiological mechanism behind this phenomena, we developed a neuronal model which takes into account the fact that peripheral vision involves a relatively fewer number of neurons with large spatial uncertainty (receptive fields). Assuming the overall sensory response is reflected by pooling information over many neurons, the model gives a plausible explanation as to why peripheral vision produces sensory responses with larger variability, and thereby inflated subjective perception.

35.22, *5:30 pm*

A release from crowding using task-irrelevant object parts John Greenwood[1,2](john.greenwood@parisdescartes.fr), Patrick Cavanagh[1,2]; [1]Laboratoire Psychologie de la Perception, Université Paris Descartes, Sorbonne Paris Cité, [2]UMR 8158, Centre National de la Recherche Scientifique

Objects in our peripheral vision are difficult to identify in clutter. This deleterious integration, known as crowding, is strongest when objects are similar in appearance (e.g. all green) and weak when the target object is distinct (e.g. red amongst green). At present, it is not known how this selectivity applies to more complex objects composed of multiple parts. For instance, can a whole object be saved from crowding if only one of its parts differs from the flankers? We examined this using object parts that were both relevant and irrelevant to the required task. Our objects were composed of three parts: an outer circle, a near-horizontal bisecting line, and a central dot (all matched for surface area and luminance). Observers judged the orientation of the target bisecting line (±10deg. of horizontal) at 10deg. eccentricity, either in isolation or with four abutting flankers. Objects were either wholly coloured (red or green) or selectively coloured with one of the three parts rendered red/green and the remainder in grey. The colouring of the target either matched or differed from the flankers. In all conditions, performance was poor when target and flanker colours matched, and greatly improved when the target was differentially coloured. That is, colour differences reduced crowding regardless of whether the difference applied to the whole object or just individual parts. This was true even for the inner-dot and outer-circle parts, which were entirely uninformative for the orientation task. Because positional uncertainty was low in our experiments, the colour difference was not simply a cue to the target location. Rather, our results suggest that when any part of a target differs from surrounding objects, the whole target is saved from crowding. The release from crowding may thus involve high-level mechanisms that are tuned for objects rather than individual feature dimensions.

Acknowledgement: Funded by a Marie Curie Intra-European Fellowship (JG) and the Agence Nationale de la Recherche (PC).

35.23, *5:45 pm*

Quantifying Error Distributions in Crowding Deborah Hanus[1](dhanus@mit.edu), Edward Vul[2]; [1]Brain and Cognitive Sciences, Massachusetts Institute of Technology, [2]Psychology, University of California, San Diego

When similar visual objects interfere in the periphery, the percept is "crowded," and observers have difficulty identifying a target object. We aim to characterize the types of errors produced in crowding by parameterizing subjects' responses via statistical models embodying principles of spatial substitution and spatial pooling of crowded objects. Subjects saw an array of nine random letters arranged in a semi-circle centered on fixation and reported the identity of the cued target letter. In separate experiments, we manipulated the spacing between items, eccentricity of the letter array and duration of the precue, indicating the target location prior to letter array onset. Because all presented items were unique, we could identify the position of reported intrusions, enabling us to characterize patterns in the subjects' errors and compare them to errors predicted by models embodying spatial substitution and pooling mechanisms. We find that characterizing subjects' responses requires accounting for the pairwise confusability of individual letters, as well as variations in flanking letters' influence as a function of space. However, once both letter confusion and spatial weighting are considered, spatial substitution models (that do not consider non-additive interactions of adjacent letters) and spatial pooling models (that have non-additive interactions of adjacent letters) can capture participants' performance equally well. Finally, we investigate whether the three experimental manipulations of crowding difficulty (spacing, eccentricity, and precue) had qualitatively different effects on the types of errors that subjects produced. We considered how the parametric distribution of errors changed as a function of condition difficulty and found that all three manipulations had substantial effects on errors, but the error distributions fell on a single dimension of difficulty. Thus, it does not appear that (i.e.) precueing changes the spatial precision while spacing or eccentricity changes the individual letter confusability: all the difficulty manipulations that we tested modulate performance similarly.

35.24, *6:00 pm*

When crowding of crowding leads to uncrowding Mauro Manassi[1](mauro.manassi@epfl.ch), Bilge Sayim[1], Michael H Herzog[1]; [1]Laboratory of Psychophysics, Brain Mind Institute, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland

In crowding, target discrimination is impaired by flanking elements. What happens if a target is neighbored by flankers A and in addition by further flankers B? According to pooling models, crowding is the consequence of averaging features of target and flankers. Hence, pooling models predict strong crowding when the target is flanked by two flankers. We determined offset discrimination thresholds for verniers at 9° of eccentricity. When the vernier was embedded in a square, thresholds increased compared to the unflanked threshold - a classical crowding effect. Surprisingly, when adding more squares, thresholds did not increase, but crowding almost vanished. Hence, crowding of crowding leads to uncrowding. We propose that this un-crowding effect can be explained in terms of grouping. Grouping between the vernier and the central square leads to crowding by the Gestalt principle of common region. Grouping of the central and the neighboring squares by the Gestalt principle of similarity, leads to ungrouping of the vernier, and to un-crowding.

Acknowledgement: The SNF grant "Basics of visual processing: what crowds in crowding?" of The Swiss National Science Foundation

35.25, *6:15 pm*

The role of perceptual organization in crowding Cathleen M Moore[1](-cathleen-moore@uiowa.edu), Anthony Chung[1]; [1]University of Iowa

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Crowding is characterized by an impaired ability to identify stimuli in the context clutter. Critical spacing, defined as the minimal distance by which stimuli must be separated to achieve criterion-level performance, increases with increasing eccentricity. Fixed-property models hold that critical spacing is determined by fixed properties of the visual system, such as fixed integration fields or fixed attentional resolution at given eccentricities. Fixed-property models, however, seem inconsistent with observations that when a target stimulus is distinguished from flanking stimuli by, for example, contrast polarity, crowding can be substantially reduced. These results suggest that representing target stimuli as objects that are distinct from surrounding stimuli may protect them from crowding because integration/selection processes are mediated through object representations. We tested this hypothesis by asking whether the object history of stimuli can protect a target from crowding even if there are no featural distinctions (e.g., contrast polarity) in the crowding display itself. Displays began with movies of identical gray squares moving along random paths. In one condition the squares moved coherently along a single path, thereby encouraging a representation of a single coherent, if complex, object. In the other condition, the squares moved along a separate paths, thereby encouraging representations of distinct objects. In both conditions, the motion ended with one square in the middle surrounded by four other squares and gaps appeared in one side of each square. Observers reported the gap position for the center square. Thus the displays in which the target was identified were identical across conditions; they differed only in their history and whether the center square had been perceptually encouraged to be represented as distinct from the surrounding squares or not. Less crowding was observed in the separate-motion condition than in the coherent-motion condition. These results rule out basic fixed-property models of crowding.

Acknowledgement: NSF BCS-0818536

35.26, *6:30 pm*

SSVEPs indicate that grouping limits resolving power of attention inducing crowding Jeff Nador[1](jeff_nador@hotmail.com), Yury Petrov[1], Jiehui Quian[1]; [1]Northeastern University

It is known that target pop-out reduces crowding (Kooi et al., 1994; Poder, 2006) and, conversely, target-flanker grouping increases it (Sayim et al., 2011). This indicates that global rather than local factors underlie crowding. Attention is one such factor. Previously, we have demonstrated a strong effect of the distribution of attention on crowding (Petrov & Meleshkevich, 2011). Intrilligator & Cavanagh (2001) explain crowding based on the resolution limit of spatial attention in the periphery, but they do not explain this limit. Here we provide evidence for a new hypothesis where the target-flanker grouping is instrumental in setting this limit. Two target Gabors were presented 8 deg. left and right of fixation, 36 flanker Gabors formed a uniform texture around each target. Steady state visually evoked potentials were used to frequency-tag target and flanker Gabors contrast reversing at two different frequencies. We measured EEG amplitude at the flankers' second harmonic frequency in three conditions: flankers of the same orientation and contrast as the target (crowded condition), flankers of orthogonal orientation or lower contrast with respect to the target (pop-out condition), and the latter with attention directed away by a foveal task (unattended condition). In the first two conditions attention was directed to the targets by a target-related task. A separate psychophysical experiment confirmed strong crowding in the first condition and weak or no crowding in the second condition. We observed a significant decrease in flanker responses in the pop-out condition compared to the crowded condition and a similar decrease in the unattended condition. Importantly, the two effects were significantly correlated across observers ($n = 22$, $p < 0.001$). We hypothesize that when target-flanker array elements group, spatial attention involuntarily spreads over the whole array (strengthening flanker responses) inducing crowding. When the target pops-out, attention narrows to the target area reducing crowding.

35.27, *6:45 pm*

The power of pooling in high dimensions Ruth Rosenholtz[1,2](rruth@mit.edu); [1]Brain & Cognitive Sciences, [2]CSAIL, M.I.T.

Evidence suggests that crowding results from "forced texture processing," involving excessive feature integration or compulsory averaging over each local pooling region. A number of experiments have tested a simple version of this hypothesis. In this simple pooling model, each pooling region yields the mean of some (often unspecified) feature. To a first approximation, this predicts worse performance the more one fills the pooling region with irrelevant flankers. For a given amount of "flanker stuff", performance should not depend on the perceptual organization of the flankers, nor on the flanker identities, except insofar as they affect the informativeness of the mean feature value. This impoverished model cannot explain performance improvements with larger flankers (Levi & Carney 2009; Manassi et al 2012), or when flankers group with one another (Saarela et al. 2009; Sayim et al 2010; Manassi et al. 2012). It cannot predict worse performance with increasing target-flanker similarity (Andriessen & Bouma 1976; Kooi et al 1994; Saarela et al. 2009), unless one hypothesizes that averaging occurs only within a narrow feature band. And why do observers not merely report the mean? These results seem to bode ill for pooling models of crowding. However, the model being rejected is a straw man. Realistic texture processing models are high-dimensional, and bear little resemblance to their low-dimensional brethren. High-dimensional models behave fundamentally differently, and intuitions do not simply "scale up" from low-dimensional models. More measurements per patch provide increasingly good representation of that patch. I will demonstrate simple techniques for gaining intuitions about high-dimensional models. Such models can capture the "objectness" and numerosity of display items, aspects of their feature distributions (not just their mean), differences between target and flankers, and flanker grouping. Such information can facilitate decision-making about the target in ways not predicted by a "simple pooling model".

Acknowledgement: NIH R01-EY021473

35.28, *7:00 pm*

Texture mechanisms pool multiple first-order channels Michael Landy[1,2](landy@nyu.edu), Zachary Westrick[1]; [1]New York University, Dept. of Psychology, [2]New York University, Center for Neural Science

The filter-rectify-filter (FRF) model is a popular model of texture segregation. In FRF, images are (1) processed by linear filters to isolate a constituent texture, (2) rectified yielding a texture-intensity image, and (3) filtered again to detect the texture-defined signal. In FRF there is an interaction between first-stage filter bandwidth and second-order contrast sensitivity: If the first-stage filter is tuned for the texture carrier with typical bandwidth for V1, predicted sensitivity to high-frequency texture modulation is much lower than measured human sensitivity. Human performance is consistent with an FRF model with much higher first-order bandwidth. We report two tests of the following hypothesis: Second-order mechanisms achieve broad first-order bandwidth by pooling over multiple first-order channels to preserve high-frequency second-order sensitivity. Methods: Expt. 1: Cross-carrier adaptation. Observers adapted to a second-order grating. We measured detection threshold (2IFC) for a second-order grating with identical second-order spatial-frequency, but possibly differing in orientation and/or carrier frequency from the adapter. We estimated the degree of orientation-specific, cross-carrier adaptation as the ratio of detection thresholds for same vs. different second-order orientation (relative to adapter orientation). Expt. 2: Dependence of threshold on carrier contrast: We measured threshold for orientation discrimination (vertical vs. horizontal second-order grating, 2AFC) as a function of second-order spatial frequency and first-order carrier contrast. Results and Conclusions: Expt. 1: We found cross-carrier adaptation even when carriers differed by a factor of four, indicating that second-order mechanisms are sensitive to a broad range of carrier frequencies. Expt. 2: Relative sensitivity to high-frequency gratings dropped dramatically with reduced first-order contrast. This is because detection of a high frequency modulator depends on first-order responses to frequencies distant from the carrier that drop below threshold at low contrasts. Both results are consistent with second-order mechanisms that receive input from first-stage filters with diverse tuning properties.

Acknowledgement: NIH EY08266

Sunday Afternoon Posters

Attention: Spatial selection 1

Sunday, May 12, 2:45 - 6:45 pm

Poster Session, Royal Ballroom 6-8

36.301 **A unified framework for multiple-alternative detection in birds and primates** Devarajan Sridharan[1](dsridhar@stanford.edu), Nicholas Steinmetz[1], Tirin Moore[1], Eric Knudsen[1]; [1]Department of Neurobiology, Stanford University School of Medicine, Stanford, California

Studies of spatial vision and attention seek to measure sensitivity to visual stimuli at multiple locations within a single experimental session. A key challenge for behavioral psychophysics is to decouple the contributions of perceptual sensitivity from those of response bias at each location. Signal detection theory (SDT) is a powerful approach for decoupling sensitivity from bias in two alternative forced-choice (discrimination) and Yes-No (detection) tasks. However, conventional SDT cannot be readily applied to tasks with more than two response alternatives. Here we introduce a theoretical framework that extends SDT to a detection task with multiple (more than two) alternatives. In multiple-alternative detection tasks, targets are presented at one among several potential locations, and the subject is rewarded for detecting and indicating the location of the target (when it occurred), or for not responding when no target was presented ("catch" trials). Based on a structural model and decision rule, our framework permits principled estimation of sensitivity and bias at each location from observed response probabilities. We applied this framework to estimate sensitivity and bias for chickens (Gallus domesticus) and monkeys (Macaca mulatta) performing four-alternative visual detection tasks. In each task, the target could occur at one of four locations (one in each visual quadrant) or not at all (catch), generating a 5x5 contingency table of response probabilities. For both species, the theory demonstrated remarkable predictive ability: with parameters estimated from only 8 contingencies (the 4 miss and 4 false-alarm rates) response probabilities for all remaining 17 contingencies could be predicted with less than 3% deviation. Our results demonstrate that a common model accounts for spatial detection behaviors in these diverse species. This framework will find important application in assessing the differential effects of neural manipulations (microstimulation or inactivation) on sensitivity and bias in multialternative detection tasks of spatial vision and attention.

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36.302 **Perifoveal spatial compression** Eckart Zimmermann[1](ec.zimmermann@fz-juelich.de), Gereon Fink[1,2], Patrick Cavanagh[3]; [1]Cognitive Neuroscience, Institute of Neuroscience and Medicine (INM-3), Research Centre Jülich, Germany, [2]Department of Neurology, University Hospital Cologne, Germany, [3]Laboratoire Psychologie de la Perception, Centre Attention Vision, CNRS UMR 8158

Perception of location is vulnerable to large errors around the time of a sudden event like abrupt stimulus motion or an eye movement. We found a strong compression of space in the absence of eye or image motion where brief probes were attracted toward a visual reference that was followed by a mask. The visual reference presented in the near-periphery was followed after 100-180 ms ms by a brief whole-field mask. At various times around the mask onset, a probe dot was flashed. Subjects had to estimate the position of the probe in relation to a comparison bar. The probe location was perceived nearly veridically when presented long before or after mask onset. However, when the probe was presented within 50 ms of the mask, it appeared shifted toward the reference by as much as 50 percent of their separation. The reference had to appear briefly before mask onset to attract the probe dot. No compression occurred when the reference was presented long before or after the mask. When we presented the probe and reference with similar brief durations, the more peripheral stimulus always shifted toward the more foveal stimulus independently of their temporal order. We suggest that the attraction can be explained by the summation of the neural activity distributions of probe and reference. Underlying the observed effect might be a mechanism that tries to establish spatial continuity of changing objects. The perception of two flashed objects, reference and probe, offset in space an time would normally trigger the perception of apparent motion. However, if the transient of such a motion is masked, then the two objects will appear closer to each other to match the reduced transient strength.

36.303 **Sustained spatial attention excludes external noise** Yukai Zhao[1](yukai.zhao@usc.edu), Zhong-Lin Lu[2], Alexandre Pouget[3,4], Barbara Anne Dosher[5]; [1]Neuroscience Graduate Program, University of Southern California, [2]Laboratory of Brain Processes (LOBES), Department of Psychology, The Ohio State University, [3]Department of Brain and Cognitive Sciences, University of Rochester, [4]Department of Basic Neuroscience, University of Geneva, Switzerland, [5]Memory, Attention and Perception Laboratory (MAPL), Department of Cognitive Sciences and Institute of Mathematical Behavioral Sciences, University of California, Irvine

The mechanism of attention is a central topic in neurophysiology, functional imaging, and behavioral studies. However, neurophysiology experiments often study cellular responses when the animal attends to one location for a prolonged period of time (sustained attention1), while human behavioral studies often use pre-cues to direct subject's attention to different locations trial by trial (transient attention2). Here, we conducted a human behavioral study based on a sustained attention paradigm more often used in a monkey experiment 1 . Four synchronized RSVP streams of Gabors were presented in each trial. Each stream consisted of 10 distractors, all oriented at 45° clockwise, and one potential target, ±11° from 45°, that occurred between the 3rd and the 10th temporal positions. The four potential targets, presented in the four locations simultaneously, had independently chosen orientations. Subjects were instructed to maintain fixation (monitored by an eye-tracker) and attend to one of the four locations throughout each block of trials. A central report cue, presented 150 ms after the target presentation and consistent with the block cue 62.5% of the time, directed the subjects to report the orientation of the target in the cued location. In the invalid condition, the report cue pointed to one of the other three locations with equal probability. Full psychometric functions were measured at 4-5 external noise levels. Block cuing improved performance only in high external noise conditions for three out of four subjects. The other subject showed no significant attention effect. The data were fit with the perceptual template model 3. Consistent with studies on transient attention 2, we identified an external noise exclusion mechanism in sustained attention. (1.Cohen & Maunsell, 2009; 2. Dosher & Lu, 2000; 3. Lu & Dosher, 1998)

Acknowledgement: National Institute of Mental Health, MH081018

36.304 **Pre-cues alleviate supercrowding without attracting focal attention** Joshua Solomon[1](J.A.Solomon@city.ac.uk); [1]Optometry and Visual Science, City University London

The so-called "exogenous" spatial pre-cues, which precede the appearance of a target by ~100 ms, can facilitate all sorts of visual tasks, including target identification in the presence of flanking stimuli. In other words, pre-cueing diminishes crowding. In order to determine whether a facilitatory pre-cue engages focal attention, its effect can be compared with that of several, simultaneously displayed pre-cues. If the latter facilitate performance (only) with nearby targets just as much as the former, spatially focussed attention is unlikely to be involved. Such is the case with "supercrowding," wherein a post-mask exacerbates the effect of flanking stimuli on target identification. At this time it remains unclear which, if any, facilitatory effects ascribed to pre-cues actually involve focal attention.

Acknowledgement: This research was funded in part by a grant from the Engineering and Physical Sciences Research Council of Great Britain (grant # EP/H033955/1).

36.305 **The influence of graded spatial attention on human direction discrimination thresholds as a function of stimulus motion coherence** Vera Marks[1,2](vmarks@dpz.eu), Stefan Treue[1,2]; [1]Cognitive Neuroscience Laboratory, German Primate Center, Goettingen, [2]Faculty of Biology, University of Goettingen, Germany

We investigated the influence of covert spatial attention on the perception of visual motion in human subjects. In our paradigm, an exogenous cue was used to attract the spatial attention of subjects to one of two random dot patterns (RDP, diameter 5 deg, moving at 8 deg/s within stationary virtual apertures), centered at 5 degrees eccentricity to the left and right, respectively, of a central fixation point. Importantly, we aimed to manipulate the amount of spatial attention deployed by varying the validity of the cue. The target stimulus was a brief coherent motion signal (75 ms)

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within one RDP, which was accompanied by a contralateral and followed by a bilateral RDP mask containing a mixture of all possible directions of motion. By using different levels of cue validity, we created four attentional conditions (100%, 75%, 50%, 25%). Direction discrimination thresholds of well-trained subjects were measured using a 4-alternative forced-choice (4AFC) direction discrimination task. They were asked to report the location (left or right) as well as the motion direction (up or down relative to horizontal) of the target stimulus by pressing one of four buttons. Using such a 4AFC discrimination task, true attentional effects can be discriminated from effects of stimulus uncertainty. We additionally used blocks of trials with four different levels of motion coherence (40%, 60%, 80%, 100%) in the target stimulus. Our results show that the validity of the cue affected subjects' discrimination thresholds in a graded manner, i.e. 100% attention to one location resulted in highest performance whereas 25% attention led to the weakest performance, approximately doubling the discrimination threshold. Motion coherence also affected performance, with discrimination thresholds increasing with decreasing levels of motion strength. These two effects on performance seem to operate independently, with no interaction found between coherence and level of graded attention.

36.306 **Object substitution masking depends on the sizes of both stimulus and attention field**

Si On Kim[1](htmw@yonsei.ac.kr), Sang Chul Chong[1,2]; [1]Graduate Program in Cognitive Science, Yonsei University, [2]Department of Psychology, Yonsei University

A previous study (Enns and Di Lollo, 2000) reported that the amount of object substitution masking (OSM) is influenced by the number of distractors in an orientation discrimination task. The current study investigates how the amount of OSM is influenced by the sizes of stimulus and attention field. Stimuli were Landolt Cs, and their size was either 1.2° (small) or 2.4° (large). Each display had four Landolt Cs, and each Landolt C was presented either at 1.4° (close) or 2.8° (far) away from the fixation cross. Note that we did not present large stimuli in the close distance. We also varied the duration of a trailing mask in five levels (12ms, 52ms, 104ms, until response, and no mask). Four Landolt Cs were presented simultaneously for 12ms, and one of them was presented with four dots. After 52ms, only four dots reappeared for the pre-specified duration. Participants were asked to report the orientation of the Landolt C presented with four dots. We found that the orientation discrimination did not differ between the small-close and large-far conditions but significantly differed between the small-close and small-far conditions. The amount of OSM was the largest in the small-far condition, even when a trailing mask was presented only for 12ms. These results suggest that the amount of OSM is related to the sizes of stimulus and attention field, consistent with the prediction from the normalization model of attention (Reynolds and Heeger, 2009).

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36.307 **The effect of spatial attention on adaptation induced by visible and invisible stimuli**

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The present study investigated how attention is distributed over dominant and suppressed stimuli under binocular rivalry. The previous studies have found that the suppressed stimuli can be influenced by attention but did not examine how attentional modulation is allocated to each of the dominant and suppressed stimuli (Shin, Stolte, & Chong, 2009). It is possible that attention preferentially enhances the processing of dominant stimuli at the expense of suppressed ones, or similarly modulates the processing of both dominant and suppressed stimuli. To investigate these hypotheses, we measured the effect of attention on both of the dominant and suppressed stimuli when they were simultaneously attended. We used moving and tilted gratings for dominant and suppressed adapters, respectively, and then measured motion aftereffects (MAEs) and tilted aftereffects (TAEs) for each type of adapter. We presented both types of adapters to the left and the right of the fixation cross, thereby the dominant and suppressed adapters occupying the same location. While adapting to these adapters, participants performed a contrast decrement detection task on one of the MAE adapters, which required spatial attention. For the MAE adapters, which were dominant, we found that there was a larger amount of MAEs at attended locations than at unattended locations. However, spatial attention did not significantly modulate the amount of aftereffects from the suppressed adapters. Although the suppressed adapters were strong enough to produce a significant amount of TAEs, spatial attention enhanced the amount of TAEs only when the suppressed adapters were partially suppressed. These results suggest that spatial attention gives more priority to dominant stimuli over suppressed stimuli.

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36.308 **Examining the Locus of the Attentional Attraction Effect**

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The orienting of attention is known to distort regions of visual space. For example, a shift of attention towards peripheral cues causes the mislocalization of central vernier line targets away from the focus of attention (the attentional repulsion effect). However, by reversing the order of presentation of the vernier lines and cues, a substantial attraction effect is found (i.e., the vernier lines are now mislocalized toward the attended peripheral locations). The purpose of this study was to identify the locus of this attentional attraction effect. Participants were asked to judge the location of the top vernier line relative to the bottom line, with any attraction effect being computed as the tendency to perceive the top line as closer to the location of the cue. Unlike the repulsion effect, the attraction effect was found in an interocular display condition in which the vernier lines were presented to one eye and the peripheral cues were presented to the other eye, using LCD goggles. This result suggests that the attentional attraction effect is a higher order process as compared to the repulsion effect, and likely requires visual short term memory. To test this, we inserted either a spatial memory load task (remembering the locations of one or three squares) or color memory load task (remembering the colors of one or three squares) before the attentional attraction effect task (i.e., vernier line targets followed by peripheral cues). The results showed that occupying spatial memory reduced the magnitude of the attraction effect while the color memory load had no effect. Overall, these results indicate that the attentional attraction effect is quite different from the attentional repulsion effect, as it involves higher order visual processes that require spatial working memory.

36.309 **Depth Modulation of Attentional Repulsion and Attraction Effects**

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Shifts of visual attention produce mislocalization of visual objects. In attention repulsion effect, a brief cue that attracts attention shifts the perceived location of a following visual object away from the focus of attention. If visual cue is presented after the target, the perceived location of the targets shifted toward the location of the following cue (attention attraction). Recent research has shown that repulsion effect changes with target-cue distances (Kosovicheva et al., 2010). The present study examined one unanswered question of whether depth perception would influence the magnitudes of attentional repulsion and attraction effect. In Experiment 1, we presented cues at different depths with respect to the target to be located. The results showed that the magnitudes of both repulsion and attraction were larger when the cue was presented at the depth farther away from the target. In order examine the effect of binocular disparity, in Experiment 2, we removed binocular disparity from the stimuli used in Experiment 1 while keeping the pictorial information of depth (i.e., the retinal size of the cues and the shift in retinal position due to perspective). The attentional attraction effect was modulated in the similar ways as in Experiment 1. However, the magnitudes of the attentional repulsion effect were at the same level in all experimental conditions. These results suggest that depth perception induced by binocular disparity could modulate the magnitudes of the attentional repulsion and attraction effects differently.

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36.310 **Pupil size reflects the strategic allocation of spatial attention**

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Perceptually salient non-targets typically interfere with target processing, but such disruption can be mitigated by top-down knowledge that the salient item is not task-relevant (Geng and DiQuattro, 2010). This exploitation of statistical knowledge optimizes behavior and is thought to be underwritten by locus coeruleus – norepinephrine (LC-NE) innervation from neurons in the frontal cortex (Aston-Jones and Cohen, 2005; Minzen-

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berg et al., 2009). The two different modes of LC neuronal firing (i.e., tonic and phasic) are correlated with changes in pupil size, and the shift between these two population conditions mediates the tradeoff between behavioral exploration and exploitation (Gilzenrat et al., 2010). In this study, we investigated the relationship between pupil size and performance on a visual search task in which the probability of the target being perceptually salient was manipulated from block-to-block. Our results demonstrate that when the probability changes (e.g., the ratio of salient target to salient distracters increased from 0:100 to 30:70 to 70:30 to 100:0), a period of uncertainty ensues in which behavior is more variable and the prestimulus pupil diameter increases in size. This suggests that subjects were engaged in exploration of the task statistics during block transitions, but subsequently began to exploit the current paradigm as the new salience probabilities were learned. These results are consistent with the idea that the LC-NE system underlies the tendency to explore or exploit knowledge about environmental structure, and that pupil diameter is a viable measure of perceived task-related uncertainty that influences the strategic allocation of spatial attention.

36.312 When diverting attention improves performance: Attention trades off spatial resolution

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GOAL. Spatial resolution is maximal at the fovea and declines with eccentricity. Although heightened resolution is useful in most circumstances, it is not always optimal. For instance, in texture segmentation tasks constrained by spatial resolution, increased resolution can be detrimental. In these tasks, performance peaks at mid-periphery, where resolution is optimal for the texture scale, and drops at peripheral locations, where resolution is too low, and central locations, where resolution is too high. Exogenous (involuntary) attention automatically increases spatial resolution, improving performance at peripheral locations but impairing performance at central locations, where resolution is already too high (Yeshurun & Carrasco, Nature 1998). Here, we investigated whether and how exogenous attention affects performance at unattended areas in texture segmentation tasks. Methods. Observers had to detect (Exp.1) or discriminate the shape of (Exp.2) a texture patch embedded in a texture display. The patch could appear at several eccentricities along the horizontal meridian. Exogenous attention was manipulated using uninformative peripheral precues. With valid cues, the locations of the precue and response cue matched, with invalid cues, they did not. Cueing effects were evaluated against a neutral (distributed) attention condition. Response cues were used to eliminate location uncertainty. Eye fixation was monitored. Results. Consistent with previous studies, in both experiments we found that: (a) performance in the neutral condition peaked at mid-periphery; (b) valid cues improved performance at peripheral locations, where resolution was too low, and impaired performance at central locations, where resolution was too high. Interestingly, with invalid cues, performance decreased at peripheral locations but improved at central locations, where higher resolution hinders performance. Conclusion. Our results depict exogenous attention as an inflexible attentional mechanism that trades off spatial resolution–increasing resolution at the attended location while decreasing it elsewhere. This decrement in resolution at unattended areas reveals a paradoxical situation in which diverting attention actually improves performance.

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36.313 Evidence for dissociable endogenous and exogenous attentional maps

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We investigated whether saccade target selection and the allocation of spatial attention are represented within the same or separate attentional maps. In two experiments a spatial location was cued either endogenously or exogenously. Participants either attended at the cued location ("Attention-only condition"), made a saccade to instructed location ("Saccade-only condition"), or attended at the cued location and made a saccade to instructed location ("Dual-location condition"). We measured the allocation of attention (to the cued and the saccade target location) using an orientation discrimination task. Competition between cued location and saccade target location should arise if attentional resources for the two are shared, and no competition should occur if resources are independent. The results from the endogenous cue task indeed revealed a competition between cued and saccade target location, as evidenced by impaired orientation discrimination performance in the dual-location condition. Additionally, we observed that saccade trajectories curved away from the cued location, suggesting a competition between saccade target and cued location within the oculomotor system. In contrast, in the exogenous cue task, there was no impairment of attentional allocation to both, cued and saccade target locations, suggesting the independent, parallel allocation of attentional resources to both locations. Furthermore, curvature of saccade trajectory was smaller, indicating only minor competition between saccade target and cued location within the oculomotor system. Our findings challenge the idea that a unitary priority map is used to guide saccades and attention. We suggest that while endogenous attention and saccade target selection seem to be represented within the same attentional map, the priority map that is related to exogenous attention is separate and its interactions with the saccadic system are limited. Combined, our findings suggest that multiple attentional maps can represent attentional targets, each of them having different access to the saccadic system.

36.314 Differential effects of one versus two hands on discriminating temporal gaps.

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Previous research has indicated that the location of the hands relative to items in the visual field can impact visual perception, particularly when the items are within graspable space. At least two explanations have been proposed for how visual processing is impacted in near hand space. First, that spatial attention is preferentially allocated to locations near the hands (Reed, Grubb, & Steele, 2006). Second, in near hand space there is facilitation of processing in the magnocellular (M) relative to the parvocellular (P) visual pathway (Gozli, West, & Pratt, 2012). A complication in comparing these theories has been differences in the hand manipulations used. Some studies altered the distance between an item and a single hand, while others compared both hands near versus far from the display. The current study addressed these differences by directly comparing single and dual hand manipulations in the same task. A temporal gap task was used requiring discrimination of a brief (10, 20, or 30 ms) offset in laterally presented items. There were four hand conditions; left, right, both, or no hand(s) near the display. Consistent with previous studies, temporal gap discrimination was better when both hands were near compared to far from the display. However, there was no benefit to discrimination for items presented near the hand when only one hand was held near the display. These results suggest that the distribution of visual attention is altered based on the positioning of the hands. Specifically, when both hands are close to the display attention is spread broadly, facilitating temporal gap discrimination. Conversely, a single hand near the display induces a more focused attended region, resulting in reduced temporal discrimination.

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36.315 Cross-modal preparatory attention is reduced in amblyopes: An ERP Study

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Previous evidence of attention deficits in individuals with amblyopia (Popple & Levi, 2008; Secen et al., 2011) has relied on studies that were conducted purely in the visual domain. However, it is unknown whether amblyopes are also impaired when visual attention is cued within the auditory domain. To test this, we recorded event-related potentials (ERPs) to examine differences in attentional orienting to an auditory cue when observing with an amblyopic (AE) vs. dominant eye (DE). While fixating, a brief auditory cue prompted observers to attend to one of two locations in the left and right visual field, where stimuli were later bilaterally presented following a 800ms cue-target-interval. The target stimulus was a tilted Gabor patch that appeared on the cued side in 5% of the trials, and on the uncued side in another 5%. In all other cases, stimuli were horizontally-oriented Gabor patches. Observers were instructed to respond via key press only when the target stimulus appeared in the cued location. Contrast and orientation of targets were adjusted prior to recordings such that each individual could achieve 75-90% accuracy on the task while viewing monocularly with each eye. To isolate cued-attention effects, ERPs recorded for contralaterally-cued events were subtracted from ipsilaterally-cued events for the AE and DE. Our preliminary results indicate that during the cue-target-interval, anterior electrodes (F7, F5, F3) showed greater modulation to the auditory cue in the DE in comparison to the AE, with two contralateral positivity peaks at 100-180ms and 200-450ms. The observed differences in event-related lateralization effects provide initial evidence of decreased attentional orienting when viewing with the AE, even when

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driven by cues in the auditory domain. As directing attention to a visual stimulus can boost the speed and accuracy of its processing, increasing this orienting response may help improve other aspects of amblyopic viewing.

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Attention: Divided, resource competition

Sunday, May 12, 2:45 - 6:45 pm

Poster Session, Royal Ballroom 6-8

36.316 Hemifield effect for high-level, but not low-level, visual stimuli.

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Does the organization of receptive fields throughout the ventral visual hierarchy constrain perception? Receptive fields are known to get progressively larger at each successive stage of visual processing, with large receptive fields in anterior regions (FFA/PPA) being primarily confined within a single hemifield. From this we predicted that performance on a behavioral task with high-level items (faces/scenes) would be better when stimuli were presented across hemifields compared to when they were presented within a hemifield. This is because during within hemifield presentation, multiple stimuli will fall within the same receptive fields and mutually interfere. Meanwhile, since receptive fields in lower-level regions (V1-V4) are too small to encompass multiple items, we predicted there would be no hemifield effect with low-level categories. In Experiment 1, participants performed a change detection task with three high-level categories: faces, scenes, and objects. As predicted, performance was better when stimuli were presented across hemifields than when presented within a hemifield ($p<0.05$ in all three cases). To test if this effect is due to the arrangement of high-level receptive fields or the existence of independent pools of attention in each hemifield, we replaced the high-level categories with two low-level categories (color/orientation) in Experiment 2. The size, location, and presentation conditions between the experiments were identical; only the stimuli differed. In this case, no hemifield effect was seen for either colors ($p=0.45$) or orientations ($p=0.32$). Finally, in Experiment 3, we found a hemifield effect with high-level objects when stimuli were presented simultaneously during the initial presentation display ($p<0.05$), but not when stimuli were presented sequentially ($p=0.61$). This suggests that within hemifield interference occurs primarily during stimulus encoding. Together, these results suggest that the organization of high-level ventral visual regions into spatial maps constrains the simultaneous perception of high-level, but not low-level, visual categories.

36.317 Simultaneous selection of multiple targets and the role of hemifield-specific resources

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Under what conditions, and at what cost, can multiple visual targets be selected at the same time? We investigated spatiotemporal properties of attentional selection using rapid serial visual presentation (RSVP) tasks. Two streams of letters were presented simultaneously, offset either horizontally (presented in different hemifields) or vertically (same hemifield), with target letters cued by a surrounding ring. In single-target conditions, a target could appear in either of the streams; in dual-target conditions, two targets appeared simultaneously, one in each stream. Observers reported the identity of each target, and a mixture model fitted to the distribution of serial position errors estimated the efficacy (probability of reporting a relevant item), latency, and temporal precision of selection. In dual-target conditions, latency was similar in both streams, suggesting that selection was simultaneous even when both streams were in the same hemifield. Furthermore, the latency and precision observed for single targets were unaffected by requiring selection of a second, simultaneous target. However, efficacy was lower when both streams were in the same hemifield than when streams were positioned in different hemifields, consistent with greater resource independence in the different-hemifields configuration. When targets were presented simultaneously to both hemifields, we found higher efficacy for selection of targets in the left hemifield than in the right; yet for single-target conditions, efficacy was higher in the right hemifield than in the left. These findings are consistent with a model—previously proposed on the basis of neuropsychological evidence—in which attentional resources of the left cerebral hemisphere are restricted to the contralateral hemifield, while resources of the right hemisphere can be flexibly allocated to processing contralateral or ipsilateral stimuli. While some tasks may require serial shifts of attention (e.g. Holcombe, Linares, & Vaziri-Pashkam, 2011), the present results suggest that selection of targets in multiple RSVP streams can occur simultaneously.

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36.318 Attentional Boost and Attentional Load: A Study of their Interaction

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Typically, whenever one task requires more attention, performance on a second task suffers. However, although target detection exerts greater attentional demand than distractor rejection, target detection enhances, rather than impairs memory for concurrently presented and unrelated scenes (the attentional boost effect). To better understand the nature of this enhancement, we examined whether increasing the perceptual and cognitive load of the detection task decreases the magnitude of the attentional boost effect. In several experiments participants pressed a button whenever a particular target symbol appeared in a stream of other colored symbols. At the same time, a series of scenes appeared behind the symbols. We manipulated perceptual load by varying the perceptual similarity between the target and distractor symbols. Participants responded more slowly to targets that were perceptually similar to distractors than to targets that were not. However, the attentional boost effect was equally robust for these two types of targets, suggesting that it overcomes the negative effects of increasing perceptual load. In contrast, increasing cognitive load had clear detrimental effects on the attentional boost effect. When participants had to keep the two most recent target letters in memory, rather than the most recent target letter, the attentional boost effect was eliminated. These data are consistent with the claim that target detection opens an attentional gate that briefly enhances the perceptual processing of coinciding information. This enhancement offsets and masks the negative effects of increased perceptual load. However, if working memory is occupied by another task, post-perceptual processing of the scenes is impaired. Without working memory resources, better perceptual representations do not result in better long-term memory. We conclude that the attentional boost effect can facilitate perceptual processing, but is dependent upon the availability of working memory resources to solidify its effects in long term memory.

36.319 The Benefits of Automatic Inhibition

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People often encounter situations in which different visual inputs contradict each other and the influence of one input must be controlled and restricted . This restriction involves cognitive inhibition. Lately I have showed (Goldfarb, Aisenberg, & Henik, 2011), that the influence of automatic inhibition is much stronger than the intended inhibition. In that study we used the social priming technique to trigger automatic inhibition. Social concept priming tends to trigger automatic behavior that is in line with the primed concept, hence in that study participants were primed with the social concept ''dyslexia'' before performing the Stroop task. Because dyslectic people are perceived as having reading difficulties, we assumed that the social concept ''dyslexia'' would trigger the automatic common" do not read the word". We found that in the Stroop task in which participants need to ignore the word dimension, the Stroop effect was reduced and even failed to reach significance after the dyslectic person priming. Accordingly, the current study examined whether automatic inhibition is also available for intentional use and consequently if we can improve intentional inhibition abilities by performing automatic inhibition training. This study compared the improvement in the Stroop task as a result of different practice phases: In Exp. 1 the practice phase involved training in automatic inhibition (social priming of "dyslexia"), in Exp. 2 it involved non-automatic inhibition, and in Exp. 3 this phase involved a control - non inhibition task training. The results revealed that practicing automatic inhibition leads to the most improvement in the mental control mechanism.

36.320 Programming the Brain

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According to Turing's original definition, the universal computer is driven by a program tape, which determines the response to any read input on the data tape. Interestingly, and essentially, the program tape itself is also subject to change, a re-programming of the computer. The brain is certainly a universal computer in this sense, and a number of research directions touch on its re-programming aspect, including: attention, task-switching, executive control, and perceptual learning. But even taken together, these elements do not contain the full nature of our brain's being a universal computer, rather than single-task machine. Choosing a program is necessary even when there is no competition for limited resources; (is "O" to be read as a number, as in O,1,2 or as a letter, as in M,N,O,P), and it contains more than contextual relationships. At the same time, choosing a program is also more than determining a set of stimulus-response associations, and it may entail also the choice of an appropriate computational algorithm. I will define these terms to determine the programming and re-programming elements within each paradigm. I will demonstrate examples of task switching, its benefits and costs, and and an example of a dual-task situation where participants actually get better at one task when the other gets too hard. It is as if a central executive within the brain determines that it is wasteful to expend limited shared resources on a task that will fail anyway, and is more cost-effective to concentrate efforts on the task that is more likely to succeed. Thus, the brain not only switches among programs, task sets or schema, it decides how to do this switch on the basis of complex cost-benefit analyses.

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36.321 **Short-term fatigue of perceptual decision making and metacognition**

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In psychophysics experiments we typically give subjects short breaks between blocks of trials, presumably because they get "tired". Whereas earlier studies suggest it is difficult to maintain attention and vigilance over long periods of time, it is unclear precisely what mechanisms can benefit from rests after a short block just a few minutes. Here we show that within short blocks of 100 trials (approximately 5 minutes), there were clear instances of drops of both basic perceptual decision performance, as well as sensory metacognition capacity (i.e. how well one can introspectively distinguish between correct and incorrect perceptual decisions, by placing appropriate confidence ratings). Importantly, these two forms of short term "fatigue" effects show a trade-off relationship. In subjects whose basic perceptual performance was well maintained over time, the metacognitive fatigue effect was stronger. This result violates the prediction of a single-process signal detection model in which the same mechanism gives rise to both perceptual decisions and confidence. However, despite the dissociation, the two mechansims likely depend on common resources, which explains the trade-off relationship between the two. Based on structural MRI brain images of individual subjects, we assessed the gray matter volume of their frontal polar area, a region that has been linked to visual metacognition. We found that this region may play a role in supplying the common resources that support both the maintenance of perceptual performance and metacognition, as variability of its volume accounts for individual differences in behavior. This model is further tested by two experiments in which reduced demand of metacognition led to better maintenance of perceptual performance over time. Overall, these results support the view that during breaks between short blocks, it is the higher-level perceptual decision mechanisms, rather than low level sensory machinery, that benefit most from rest.

36.322 **Divided Attention While Walking: Examining Functional Changes in Prefrontal Activity in Translational Contexts**

Joanna Lewis[1](joanna.lewis@knights.ucf.edu), Audrey Hill[1], Corey Bohil[1], Mark Neider[1]; [1]Department of Psychology, University of Central Florida

Recent research has demonstrated our limited ability to divide attention between two tasks, such as when walking while talking on a cell phone (Neider et al., 2010). However characterizing performance costs in these types of dual-task scenarios, particularly those in the translational context, has previously been limited to measurement of task errors and completion times. Our study addressed this by using a portable functional near-infrared spectroscopy (fNIRS) system to characterize changes in functional activity in dorsolateral prefrontal cortex (PFC) while participants walked and performed backward counting tasks of varying attentional load. Previous research found that PFC recruitment increased when cognitive load increased from a single-task (walking) to a dual-task (walking while talking) (Hotzler et al., 2011). Accordingly, we expected additional increases in secondary task difficulty to correlate with increased PFC activity. All participants completed a series of 25 ft walks, both with and without a secondary task. Attentional load was manipulated between-subjects (7 low load; 7 high load) by varying backwards counting increments (either by 1's/low load or 7's/high load). Participants in the low load condition made significantly fewer counting errors and completed more counting iterations than those in the high load condition. PFC activity increased generally for the high load condition compared to walking only, but low load did not significantly change as compared to the control condition. Importantly, no differences in PFC activation were found between groups in the walking-only trials. These data support the hypothesis that the increased effort associated with divided attention while walking is reflected in increased PFC recruitment; the more demanding the attentional load the greater the demand on neural resources. We speculate that limitations in these resources might be the determining factor in dual-task related performance failures.

36.323 **Does the disadvantage of media multitaskers in task switching lie in the change of cue or task?**

Kelvin F. H. Lui[1](f2a8kelvin@yahoo.com.hk), Alan C.-N. Wong[1]; [1]Department of Psychology, The Chinese University of Hong Kong

Heavy media multitaskers (HMMs) are found to be inferior to light media multitaskers (LMMs) in cognitive functions such as updating and maintenance of working memory representations, selectively attention, and surprisingly, the ability to switch between tasks. Research on task-switching paradigm using a 2:1 mapping between cues and tasks separates the total switch cost into costs related to two distinct, serial processing stages. The first type of cost is caused by a change in the task-indicating cue. The second type of cost is caused by a change of the task set and has been regarded by some as the actual task-switch cost. In the current study, we examine which stage(s) are affected by media multitasking experience. Thirty HMMs and thirty LMMs as determined by an online media-use questionnaire participated in a cued task-switching experiment involving a word typing task and a face gender classification task. The overall switch cost in response time was decomposed into two components: (a) the cue-switch cost as a result of a change of the cue with the task unchanged; and (b) the task-switch cost, which represent the switch cost not accountable by the cue-switch cost. HMMs showed a significantly larger cue-switch cost than LMMs, while the task-switch cost was similar for the two groups. Results suggest that HMMs may only be inferior in the cue-driven retrieval process of task set but not in the task-rule application stage. We are also exploring the result patterns for groups with different sub-types of media multitasking experience, and how media multitasking interacts with action video game playing experience.

36.324 **Some visual relation judgments are limited to a single dimension at a time**

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Across the visual system, absolute values are recoded into relative or opponent values for features such as luminance, motion, and color. These types of recoding occur simultaneously for multiple dimensions, perhaps because they only require spatially local processing. Here we ask whether we can simultaneously process relations for multiple dimensions when values are located in spatially separated objects. Previous work shows that we can simultaneously compare multiple values across spatially separated objects (e.g., Santee & Egeth, 1980; whether two shirts differ in both color and stripe pattern), but no existing work tests whether this is possible for relations (e.g., whether one shirt is darker and has wider stripes than the other). We tested this idea by asking participants to detect either value or relation changes for a single dimension and determined whether changes in a second irrelevant dimension influenced performance (dimensions counterbalanced across subjects). Participants detected changes across sequential displays of pairs of circular gratings that varied in both contrast and spatial frequency. In the values task, participants judged whether the two pairs had exactly the same values, and either one or both values could change. Consistent with past work, changes in the second irrelevant dimension interfered ('same' responses were slower when values in the other dimension differed), suggesting that values were compared across both dimensions at once. The relation task was identical, except that all absolute values always differed, and instead participants detected changes to the relative values (e.g., is the left object still darker than the right object?). Changes in the second irrelevant dimension no longer interfered, suggesting that only a single relation was recovered at a time. In contrast to local recoding mechanisms, we suggest that when values are spatially separated, extracting their relative values requires the use of far more capacity-limited processes.

36.325 **Individual differences in electrophysiological responses to performance feedback predict AB magnitude**

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The attentional blink (AB) is observed when report accuracy for a second target (T2) is reduced if T2 is presented within approximately 500 ms of a first target (T1), but is relatively unimpaired at longer T1-T2 separations. The AB is thought to represent a transient cost of attending to a target. There are reliable individual differences in AB magnitude. It has been suggested in some models of the AB that cognitive control contributes to the production of the AB, such that greater cognitive control is associated with larger AB magnitudes. Performance monitoring functions are thought to modulate the strength of cognitive control, and those functions are indexed by the event-related potentials in response to both endogenous and exogenous performance evaluation. Here we examine whether individual differences in the amplitudes to internal and external response feedback predict individual AB magnitudes. Electrophysiological responses to externally provided performance feedback, measured in two different tasks, predicted individual differences in AB magnitude such that greater feedback-related N2 amplitude was associated with larger AB magnitudes regardless of the valence of the feedback.

Acknowledgement: NSERC

36.326 Investigating the flanker effect with high-level visual stimuli

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In the flanker task, participants respond slower to the target in the presence of incongruent distractors than in the presence of neutral distractors, demonstrating the occurrence of a response conflict in the incongruent condition. The flanker effect has been used extensively to study the interaction between perception and action. Interestingly, the effect has been demonstrated almost exclusively with low-level visual stimuli (e.g., shapes, colors). The present study examined response interference in the flanker task using high-level visual stimuli. In Experiments 1-3, two objects (chairs) were assigned to two responses (a third object (chair) served as the neutral distractor). In Experiment 1 a central target was flanked by two congruent, incongruent or neutral distractors. The results showed a small repetition effect from the congruent (identical) distractors, but no interference from the incongruent distractors (i.e. RT was similar in the incongruent and neutral conditions). We hypothesized that the lack of interference could result from perceptual limitations in processing the lateralized distractors. Therefore, in Experiment 2 a single central (congruent, incongruent or neutral) distractor preceded the occurrence of the central target. The results showed a large repetition effect from the congruent distractors with no response interference from the incongruent distractors. In Experiment 3, the same flanker task was followed on half of the trials by a distractor recognition task, to verify that the distractor was processed. Accuracy in the recognition task was 92%, yet the incongruent distractor did not interfere with target processing. Experiment 4 showed a lack of response interference in a sequential flanker task with pictures of natural scenes. The results demonstrate a lack of response interference in the flanker task with high-level visual stimuli, and suggest that the processes that link perception and action in high-level visual stimuli may be different from those operating on low-level visual stimuli.

36.327 Blur Detection In Natural Scenes Is Not Affected By Cognitive Load

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Does the detection of image blur require attention? Perhaps not, since image blur affects saccade target selection; with the eyes avoiding blurred extrafoveal image regions (Geisler, Perry, & Najemnik, 2006; Loschky & McConkie, 2002). Conversely, attention affects spatial resolution in many psychophysical tasks (Carrasco, 2011), so cognitive load could decrease blur sensitivity by reducing available attentional resources. To test this hypothesis, we had subjects detect image blur while looking at real-world scenes in preparation for an easy picture recognition memory task, while simultaneously carrying out an N-back task to manipulate cognitive load. Subjects were required to detect gaze-contingent blur that was presented on every 7th fixation (using an EyeLink 2000) at four different retinal eccentricities (0, 3, 6, and 9 degrees), under four levels of cognitive load (N-back: 0, 1, 2, and 3-back), and two control conditions (single-task blur detection both with and without to-be-ignored N-back letter presentations). Cognitive load was varied between blocks of trials, with order counter-balanced in a 6x6 Latin Square. We measured blur detection thresholds using an adaptive threshold estimation procedure (SIAM; Kaernbach, 1990) for each retinal eccentricity and level of cognitive load. In Experiment 1, an auditory N-back task was presented, to avoid visual interference with the blur detection task. Results showed no effect of cognitive load on blur thresholds. However, there was an effect of eccentricity, with blur thresholds monotonically shifting to lower spatial frequencies as eccentricity increased. In Experiment 2, the N-back task was presented visually, with each letter presented at the point of gaze, to test whether a foveal stimulus was required to produce an effect of cognitive load on blur thresholds. Results replicated those of Experiment 1. Thus, in both experiments, we find evidence that blur detection was unaffected by the level of attentional resources available.

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36.328 Cross-Modal effects of different auditory stimuli on visual attention

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Cross-modal studies involving vision and hearing show a facilitation of responses elicit by visual target in the presence of auditory stimuli (Boyne et al., 2005). This study aimed to investigate the effects of different auditory stimuli on visual attention measured by reaction times to detection of the visual stimulus under three different experimental conditions. Participants were undergraduate and graduate students 18 to 30 years old (n=19). In experiment I participants were instructed to attend, simultaneously, two square frames subtending 4° of visual angle located 10° to the right and left of the center of the screen. The task was to key press on a joystick to the onset of a target, a white dot subtending 0.2° of visual angle presented at 154 different positions, while always fixating a small cross in the center of the visual field. Stimulus duration was brief (100ms) to avoid eye movements and concomitant attentional shifts. Experiment II was designed in a similar way but included a congruent auditory cue, i.e monotic ipsilateral 1000 Hz tone at 70 dBHL, that was presented at different cue-target stimulus onset asynchrony (750-1500 ms). Whereas in Experiment III instead of a congruent auditory cue, a white noise at 70 dBHL was presented during the entire procedure. In Experiment II reaction times in the attended region were faster when compared to Experiment I. In Experiment III participants showed longer reaction times when compared to Experiments I and II. These results suggest that an informative (spatially congruent) auditory stimulus contributed to visual attention whereas a non informative (spatially non congruent) auditory stimulus may function as a distractor of visual attention.

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36.329 Effects of attentional states on visuomotor learning

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To behave adaptively in a changing environment, humans must modify and develop new internal models (IM) via sensory-motor adaptation. This process frequently occurs in a complex environment where other stimuli compete for limited attentional resources. We previously demonstrated that dividing attention had minimal effects on visuomotor adaptation per se but significantly interfered with recall. Here we further hypothesized that attentional states themselves become incorporated within the IM. During learning, all 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 we manipulated the consistency of attentional states by having different groups of participants perform the same attentional task as during learning (repeat), or a different attentional task within the same (visual) or different (auditory) sensory modality. Thus, there were three "consistent" groups in which divided attentional states were maintained between learning and recall: repeat, visual, and auditory. We also had an inconsistent group who did not perform any attention task during recall and a control group who never performed the attentional task. During learning, visuomotor performance did not differ among groups, suggesting that divided-attention did not interfere with motor error reduction. However, at recall all consistent and control groups performed equivalently and outperformed the inconsistent group. Taken together, we demonstrated that dividing attention does not impair motor error reduction nor memory formation per se as all consistent groups recalled the IM with sucess. Rather, attentional states during learning became part of the IM and thus successful IM retrieval depends on the attentional state consistency with initial learning, independent of the specific attentional task used. Thus, our results offer a new view of how attention and procedural motor skills interact.

36.330 Attention modulates generalization of visuomotor learning

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Generalization represents the ability to transfer knowledge, e.g., motor skills, from one context to another. In daily life, motor learning often occurs in an environment where various stimuli compete for limited attentional resources. Here, we examined whether divided attention during learning alters the generalization of visuomotor adaptation. We formed No-Load and High-Load groups to perform 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' in different colors appear sequentially. The High-Load group was required to detect a conjunction "T" target (color and orientation) and report the number of detected T's (1, 2 or 3) after each trial by a button response. The No-Load group was told to ignore the RSVP stream and instead made a button response after each trial. Both groups first trained (45° CCW) in one direction (Adaptation) and then had to reach to other untrained directions (Generalization). Results showed that the RSVP accuracy in the High-Load group was 61.3% ± 4.9 (chance level was 33%), suggesting that the High-Load group allocated some attention to the RSVP task, limiting available attentional resources for the adaptation task. We found similar levels of Adaptation (i.e., reaching accuracy) for both groups, but the No-Load group had better Generalization (i.e. accuracy to untrained directions) than the High-Load group. Specifically, we demonstrated that divided attention reduced gain and sharpened tuning of the generalization function. Thus, dividing attention during learning restricts the range and gain of generalization of visuomotor adaptation, highlighting a critical role for attention in motor learning. This result might suggest that attention can modulate subpopulation(s) of neurons in motor areas, which have directional tuning in or near the training direction.

36.331 **The distribution of covert visual attention during multidigit grasping** Rene Gilster[1](rene.gilster@psy.lmu.de), Heiner Deubel[1]; [1]Department of Psychology, Ludwig-Maximilians-Universität München

It is well established that the preparation of goal directed movements such as saccades and manual reaches is accompanied by covert shifts of attention to the future target position. In the present study, we investigated the spatial deployment of attention during two- and three finger grasping of various geometric objects. The objects were attached to a vertically oriented plane and grasped with two fingers (thumb and index finger) or with three fingers (plus middle finger). The contact points with the object were self-chosen by the participant and recorded with electromagnetic sensors attached to individual fingers. In order to assess the spatial distribution of visual attention, we developed a new perceptual discrimination paradigm, the "multiple letters task". In each trial, a noise pattern surrounding the object changed into eight letters and eight distractors for 100 ms, and then post-masked by a noise pattern. The letters were chosen randomly from a larger set of 16 letters. After grasping, subjects were asked to indicate three letters they had seen during the preparation of the movement. The percentage of correctly reported letters as a function of distance from the contact positions of the individual fingers yielded the distribution of covert visual attention. The findings confirm the tight link between covert attention and movement targets also for grasping. Attention was directed to all future contact points with the object, demonstrating that multiple foci of attention are established during grasping. Our results provide evidence in favor of an "attentional landscape" that is established when more than a single location is relevant for the planning of a motor action.

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Object recognition: Categories

Sunday, May 12, 2:45 - 6:45 pm

Poster Session, Orchid Ballroom

36.401 **Understanding the nature of the visual representations underlying rapid categorization tasks.** Imri Sofer[1](imri_sofer@brown.edu), Kwang Ryeol Lee[2], Pachaya Sailamul[2], Sébastien Crouzet[1,3], Thomas Serre[1]; [1]Department of Cognitive Linguistic & Psychological Sciences, and the Institute for Brain Sciences, Brown University, [2]Dept. of Bio and Brain Engineering, Korea Advanced Institute of Science and Technology (KAIST), Daejeon, Republic of Korea, [3]Institute of Medical Psychology, Charité University Medicine Berlin, Germany

Unlike simple artificial visual stimuli that can be readily parameterized, one of the key challenges associated with the use of natural image datasets in psychophysics is that they are difficult to control. For instance, we do not yet have metrics for natural images that capture the intrinsic visual similarity between real-world object categories. It is thus hard to control for task difficulty when dealing with natural object categories, which might be a cause for confounds in existing experiments. Here we introduced a measurement of the discriminability between natural scene categories based on visual features. The discriminability measurement is obtained by first extracting image features from existing computational models of visual processing from low-, to mid- and high-level features. A classifier is then trained to discriminate between pairs of categories and an error rate is then computed on an independent dataset. This procedure was performed on 10 categories of four-legged mammals (dog, bear, gorilla, zebra, etc), and tested on participants performing 2AFC rapid categorization tasks, using all possible category pairs (average performance=83%, SD=7.9, n=4). Surprisingly, we found that low-level visual features are already highly correlated with the pattern of performance (both accuracy and reaction time) from individual participants ($r>0.80$, $p<0.001$). Our results suggest that visual similarities based on low-level visual features may account for various effects observed in visual categorization experiments, which are typically attributed to semantic aspects of visual processing. Overall, these types of visual similarity measurements might offer a unique tool to control image sets in visual recognition experiments, and further improve our understanding of the underlying visual processes.

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36.402 **Mapping visual object recognition in the human brain with combined MEG and fMRI** Radoslaw Cichy[1](rmcichy@gmail.com), Dimitrios Pantazis[2], Aude Oliva[1]; [1]Computer Science and Artificial Intelligence Laboratory, MIT, [2]McGovern Institute for Brain Research, MIT

From a neuroscientific perspective, understanding the human capacity to recognize objects requires the identification of where and when the brain processes object information. A wealth of findings shows that a hierarchical system of visual areas in the ventral visual stream enables object recognition. This system is extremely fast, and brain responses about object categories emerge in the range of 100-200ms after stimulus onset. However, most studies have limited analysis of object recognition to the level of everyday categories, leaving open questions about the representation of objects above and below the category level. In this study, we used magnetoencephalography (MEG) and multivariate pattern classification to investigate brain responses to a complex and large image set consisting of 92 images, ordered hierarchically at different levels of generality: the supra-category, category and sub-category level (Kiani et al, 2007; Kriegeskorte et al., 2008). In a first step, we investigated the time course with which information about single images emerged at different levels of generality with high temporal fidelity. We then used representational similarity analysis to link the dynamics in the evolving MEG signal to the hierarchical structure of the ventral visual stream. To this goal, we recorded brain responses to the same image set with fMRI. We showed that early MEG signals (~71ms after stimulus onset) can be linked to fMRI signals in visual area V1, whereas later on (starting at 113ms) MEG signals can be linked to human inferior-temporal cortex (IT). Taken together, our results describe the dynamics of object recognition in the human brain with high temporal fidelity, and link these dynamics quantitatively across imaging modalities to the ventral visual stream.

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36.403 **Influence of contextual priming on rapid visual categorization in monkey** Anne-Claire Collet[1,2](collet@cerco.ups-tlse.fr), Denis Fize[1,2]; [1]Université de Toulouse, Université Paul Sabatier, Centre de Recherche Cerveau et Cognition, 31062 Toulouse, France, [2]Centre National de la Recherche Scientifique, Centre de Recherche Cerveau et Cognition, Faculté de Médecine de Rangueil, 31062 Toulouse, France

Rapid object categorization is a crucial ability for animals to react and adapt their behavior to an unexpected situation. However a relevant context can help object recognition, particularly when objects are small or partially masked: several studies in both human and monkey showed that rapid visual categorization performances are improved by the categorical congruence between objects and their embedding contexts (Bar 2004, Fize et al. 2011, Joubert et al. 2007). The present study first aimed at determining whether contextual priming could also facilitate object recognition, and second whether this influence was better depicted in terms of background features accumulation or context categorical processing. Three rhesus monkeys already experts in rapid visual categorization performed an Animal vs Non-animal go/no-go task. Contextual primes consisted in Rapid Serial Visual Presentations (RSVP) of nine pictures of either natural or manmade real world scenes, randomly varying in proportion and position within the RSVP flow. These background contexts were followed, after a short 100ms delay by a flashed test stimulus containing either an object or animal isolated on a gray background. Performances were ana-

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lyzed based on the 6800, 6100 and 5800 trials that monkeys respectively performed, in terms of reaction times, accuracy and d-prime as function of natural contexts within the RSVP flow. Monkeys succeeded in this task (mean accuracy: 94.1%; mean RT=329ms), and results showed that contextual priming using an RSVP flow significantly influenced object categorization. Natural primes improved significantly Animal detectability and increased response speed. Importantly, an increasing number of natural scenes in the RSVP flow improved more generally d-prime scores in a linear way, providing further evidence for features accumulation mechanisms that integrate background and object information.

36.404 **Early categorical ERP differences: how early, how strong, how different?** Guillaume Rousselet[1](Guillaume.Rousselet@glasgow.ac.uk), Magdalena Bieniek[1], Nicola van Rijsbergen [1], Philippe Schyns[1]; [1]Institute of Neuroscience and Psychology, College of Medical, Veterinary and Life Sciences, University of Glasgow

How early does the brain decode object categories? The issue remains controversial because dynamic brain measurements are susceptible to signal drift, filtering distortions and statistical issues. Here, using single-trial distributions and a new statistical framework building on robust statistics, we present evidence that categorical differentiation occurs in the brain at 90-110 ms following stimulus onset (median onsets). Results were reliable across testing sessions, with effects starting at mid-line or lateral electrodes, depending on subjects. The results challenge findings of very early face effect <80 ms and confirm categorical sensitivity occurs at approximately 100 ms. Eight observers categorized pictures of faces, houses, and noise textures, presented for 53 ms (n=1000 trials). Seven observers were tested twice. We filtered EEG data using 2 Hz high-pass causal Butterworth filters. Causal filters drastically remove drifts that may affect onsets, but without introducing spreading of the signal in time caused by non-causal filtering. Across categories, single-trial ERP distributions could in principle differ in many ways (e.g. location, dispersion, skewness). Using classic GLMs, we found differences corresponding to changes in onset means. Kernel density estimates and shift functions revealed uniform shifts in single-trial distributions. We applied techniques sensitive to other distributional differences (i.e. mutual information, Kolmogorov-Smirnoff, and multivariate logistic regression) and confirmed that our GLM approach did not miss earlier onsets – suggesting that massively univariate GLMs are appropriate to study categorical ERP onsets. Finally, we describe non-parametric measures of ERP difference effect sizes that are comparable across studies. Although effect sizes were unsurprisingly weak at onsets, the differences were associated with strong evidence against the null hypothesis (Bayes factors > 3). Onsets of categorical differentiation are critical to circumscribe the timing of visual processes in the brain. For the first time we provide a statistical framework to unequivocally ascertain when such differentiation occurs.

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36.405 **From stimulus onset to category selectivity in 100ms: category-selective visually evoked responses as a result of extensive category learning** Tim Christian Kietzmann[1](tkietzma@uos.de), Benedikt Ehinger[1], Danja Porada[1], Andreas Engel[2], Peter König[1,2]; [1]Institute of Cognitive Science, University of Osnabrück, [2]Dept. of Neurophysiology and Pathophysiology, University Medical Center Hamburg Eppendorf

The categorization of visual input is one of the most essential challenges faced by our visual system. Despite its importance, however, the debate on the cortical origin and the timing of category-specific effects remains unsettled. Here we investigate this issue by combining extensive category training of two artificial visual categories in nine subjects with an EEG and MEG adaptation paradigm. Importantly, we estimated category effects prior to category training, and again after 24 training sessions. This allowed us to investigate the exact timing of category effects while closely controlling for low-level stimulus properties, which have previously provided extensive challenges due to potential low-level confounds in naturally occurring visual categories. High-level category-effects were assessed by means of visually evoked potentials (EEG) and fields (MEG) in response to the second stimulus of the adaptation paradigm, which could originate either from the same class as the first adapter stimulus or from the other class. Prior category training, no differences in the evoked potentials were observed, demonstrating a successful control for low-level stimulus properties. After training, however, we find significant, category-selective, differences in the rather early P100 (EEG, peak latency 108ms, p<0.05 two-tailed t-test) and M100 (MEG, peak latency 128ms, p<0.05 two-tailed t-test) components. Following this, we contrasted trials with correct and incorrect category-judgments and found significant category effects only for correct trials (p<0.05, two-tailed t-test) but not for incorrect ones (p>0.8, two-tailed t-test). This finding supports the behavioral relevance of the found category effects. In conclusion, behaviorally relevant category effects emerge as a result of category training as early as 108ms after stimulus onset. The timing and topography of the effect renders the possibility of feedback from frontal areas unlikely and rather suggests the origin of category selective representations in the ventral stream.

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36.406 **More Blobs: A Training Study Examining the Role of Medial-Frontal Cortex in the Development of Perceptual Expertise** Olav Krigolson[1](krigolson@dal.ca), Heather Gallant[1], Cameron Hassall[1]; [1]Department of Psychology and Neuroscience, Dalhousie University

In a recent study, Krigolson and colleagues (2009) demonstrated that a reinforcement learning system within medial-frontal cortex plays a key role in the development of perceptual expertise. Specifically, Krigolson et al. found that when participants learned to discriminate between two families of "blobs" feedback processing elicited an error-related negativity (fERN) – a component of the human event-related brain potential (ERP) evoked by performance feedback. Further, Krigolson et al. observed increases in ERP components associated with object recognition (N250) and response error evaluation (rERN) in participants who demonstrated behavioral learning improvements as gauged by task performance. Here, we utilized the same task at Krigolson et al. but extended training over five days so participants were exposed to 5000 learning trials. In line with the predictions of reinforcement learning theory, the amplitude of the fERN diminished with learning, and somewhat interestingly demonstrated restart costs that align with the observations of traditional learning theory. Further, and novelly, our data also provide unique insight into the N250 (object familiarity) and N170 (object expertise) visual ERP components. Specifically, we propose that the N250 is not a learned effect per se, but instead is a measure of familiarity with a basis in short term memory as we found that N250 amplitude "resets" daily dependent upon object exposure. Further, we find found that the amplitude of the N170 diminished with day-to-day learning, a result counter to studies that have examined its amplitude on a single exposure basis.

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36.407 **Birds of a Feather Flock Together...for Novices** Cindy M. Bukach[1](cbukach@richmond.edu), Tracey A. Sohner[2], Alan C. N. Wong[3], Jessie J. Peissig[2]; [1]Department of Psychology, University of Richmond, [2]Department of Psychology, California State University, Fullerton, [3]Department of Psychology, Chinese University of Hong Kong

Perceptual expertise is the ability to generalize skilled perception to novel exemplars within a category. However, what counts as a "category" may be differently for experts than for novices. For example, in a study of real-world car experts (Bukach et al., 2010) neither expert visual discrimination nor holistic processing transferred from modern to antique cars. This finding suggests that categories are more narrowly defined for experts. In this study, we tested how well expert visual discrimination of birds from the West Coast USA transferred to birds from East Coast USA and Asia on a sequential matching task modified from Bukach et al. Participants were asked to determine if sequentially presented bird images belonged to the same species. To control for visual discrimination ability, a delta d' score was calculated for each bird category (d' birds – d' cars). We tested 2 experts, 4 age-matched controls, and 19 young novices from the West Coast and 1 expert and 2 age-matched controls from Hong Kong. The West Coast bird experts showed better visual discrimination for West Coast birds than for either East Coast or Asian birds (mean delta d's = 1.87, 1.26 & 1.24, respectively). In contrast, the Asian bird expert showed the opposite pattern: better performance for Asian and East Coast birds than for West Coast birds (delta d's = 1.41, 1.51 & .74). There was no difference in visual discrimination across regions for the control groups (all mean delta d's <.5, ps >.1). These results are consistent with the idea that expert categories have a narrower structure than those of novices.

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36.408 **Category learning off of fixation causes a selective perceptual advantage for relevant dimensions.** Jonathan R. Folstein[1](jonathan.r.folstein@gmail.com), John J. Allen[1], Paige E. Scalf[1]; [1]Psychology Department, College of Social and Behavioral Sciences, University of Arizona

Learning to categorize visual objects causes a selective enhancement of visual discriminability along category-relevant dimensions. This perceptual advantage for relevant dimensions can be observed outside of

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active categorization using both behavioral and neural measures and persists days after the category learning task is over. These data suggest that although category learning certainly requires attention, its perceptual effects remain in the absence of specific attention to category relevant features. In all previous studies, however, the relevant dimension advantage is measured with the stimulus presented at an attended location. A stronger test of the hypothesis that the relevant dimension advantage is not driven by attention would be to neurally assess this advantage while the stimulus is presented at an unattended location. The first step in this research is to demonstrate behaviorally that the relevant dimension advantage can be obtained when stimuli are presented off of fixation, allowing us to direct attention away from the stimuli in future studies. We therefore trained subjects to categorize a two dimensional space of morphed cars according to a single relevant dimension of variation. Visual discriminability between cars that differed along the relevant or irrelevant dimension was measured before and after category learning. Importantly, the cars were presented 1.6 degrees above fixation during both category learning and discrimination testing. Subjects' eye movements were monitored during the task. If, during either category learning or discrimination testing, they broke fixation and moved their gaze to the car stimulus, the car disappeared immediately. Replicating our previous studies conducted with foveated stimuli, subjects' ability to discriminate between stimuli that differed along the category-relevant dimension improved significantly more than those varying along the irrelevant dimension. Future studies will measure neural adaptation effects between off-fixation stimuli with category relevant vs. irrelevant differences while subjects perform an attentional-demanding task at fixation.

36.409 **The role of sleep in consolidating semantic knowledge**

Anna Schapiro[1](schapiro@princeton.edu), Timothy Rogers[2], Kenneth Norman[1], Lang Chen[2], Elizabeth McDevitt[3], Sara Mednick[3]; [1]Department of Psychology and Princeton Neuroscience Institute, Princeton University, [2]Department of Psychology, University of Wisconsin - Madison, [3]Department of Psychology, University of California - Riverside

Though sleep is thought to play an important role in many domains of learning and memory, the impact of sleep on the acquisition of new semantic information has remained relatively unexplored. We investigated how sleep affects learning the names, category memberships, and parts of 15 novel objects ("satellites") organized into three classes. Each satellite had five visual parts, four shared by other category members and one unique to the item, as well as a class name shared by other category members and a unique code name. To learn this structure, participants guessed, with feedback, the missing part or name of one satellite on each trial. After reaching a criterion of 66% correct, participants were tested (without feedback) immediately and again later, after having slept or not, on their memory for unique and shared properties of the items, and on generalization to novel category members. In Experiment 1, half of the participants began in the evening and were tested 12 hours later after a full night of sleep, and half began in the morning and were tested after 12 hours of wake. Memory for shared properties and generalization improved over both sleep and wake, but memory for idiosyncratic properties improved only with sleep, declining over wake. Over both sleep and wake, generalization improved more for category exemplars closer to the prototype. To assess the contributions of different sleep stages to these effects, participants in Experiment 2 took polysomnographically-recorded naps between tests that contained either non-rapid eye movement (REM) sleep only or non-REM and REM sleep. Preliminary results suggest that non-REM benefited unique properties, while REM (and not simply additional sleep) benefited shared properties. We developed a neural network model that accounts for these results in terms of stronger hippocampal influence on autonomous offline learning during NREM than during REM or wake.

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36.410 **The Color of Perceptual Expertise**

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The extent to which color is used in high-level vision is contentious. Proponents of edge-based theories suggest that objects are recognized mainly based on their shape. On the other hand, surface-plus-edge-based theories support the notion that color and shape both contribute to object recognition. In favor of the latter account, objects that are strongly associated with color (i.e., high color diagnostic objects) are recognized faster when shown in a congruent color than when shown in an incongruent color or in gray-scale (Tanaka & Presnell, 1999). The extent to which this association depends on experience remains uncertain. In the current study, we examined the effects of experience and color on object recognition. In Experiment 1, expert bird watchers and novice participants were asked to categorize common birds at the subordinate level (e.g., "robin"). The bird images were shown in their congruent color, incongruent color and grey-scale. The main finding was that the expert bird watchers were faster to categorize congruent color versions of the bird images than they were to categorize incongruent color and grey-scale versions. In contrast, the novice participants were equally as fast at categorizing congruent color, incongruent color and grey-scale versions of the birds. In Experiment 2, expert bird watchers were asked to categorize congruent color, incongruent color and grey-scale images of birds at the sub-subordinate level (e.g., "nashville warbler"). Bird experts were faster to categorize congruent color versions of the birds compared to incongruent color and grey-scale versions. Collectively, the current findings demonstrate that the fast and accurate recognition of birds by expert bird watchers is facilitated by color information. Thus, perceptual experience can enhance the object representation to include color.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada (NSERC), National Institutes of Health, National Science Foundation, Army Research Institute

36.411 **Impairments in pre-semantic processing contribute to category-specific recognition deficits**

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Several accounts have been proposed to explain category-specific recognition deficits. One key theoretical question is whether category-specific deficits reflect semantic-level impairments or whether they can reflect impairments in pre-semantic processing. Here, we investigated how global shape information (particularly overall shape symmetry and complexity), and local contour information (particularly curvature) influence object identification in a patient with a category-specific deficit for natural objects (i.e., living things). We manipulated the quality of the visual representation of objects by fragmenting their outlines in a naming task. Two types of fragmentation were used: one with low curvature fragments, and one with high curvature fragments. We used a dynamic build-up paradigm with fragments increasing in length in 10 steps, and recorded the lowest presentation number (1 to 10) that resulted in correct naming. Using a dynamic build-up paradigm and survival analysis, we investigated the generation of representations of natural and manmade objects over time. We found that the patient's deficit was modulated by the percentage of outline shown, local curvature information, and global shape properties such as symmetry. Our results indicate a deficit in the dynamic build-up of representations for natural objects relative to manmade objects, indicating that pre-semantic processing impairments can contribute to the neuropsychological deficit for natural objects.

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36.412 **Sensorimotor activation for printed words in the brains of adults and children**

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Prominent "embodiment" theories argue that semantics is represented in distributed cortical networks that overlap with sensorimotor regions, and that sensory and motor activation is automatic and necessary during written word comprehension. It is unclear, however, how words become "embodied" as children learn to read. We reasoned that if sensory and motor activation is both automatic and necessary when processing word meaning, automatic picture-like neural responses for printed words should be activated as soon as printed word meaning is acquired. In contrast, if sensorimotor activation depends on post-lexical processing, automatic sensory motor activation for words may only gradually emerge as a secondary consequence of reading experience. To test these predictions we asked 21 7- to 10-year-old children and adults to perform a one-back basic level name-matching task with animal and tool pictures and their associated written words in an MRI scanner. Performance was consistent across age and conditions. All age groups showed clear differential cortical specialisation for tool and animal pictures. In adults, regions with a preference for tool or animal pictures, most notably the tool-specific left medial temporal gyrus and inferior frontal gyrus, showed corresponding activation

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patterns for tool and animal words. Thus, consistent with previous studies, object category representations were elicited merely upon presentation of the corresponding written word in adults. In contrast, even older children, who were proficient readers, showed no picture-like sensorimotor responses on the presentation of written tool or animal words, suggesting that automatic activation of semantic tool and animal networks for words emerges years after initial acquisition of word comprehension. In summary, our findings clearly show that picture-like sensorimotor activation during single word comprehension is absent in the brains of skilled reading children. This forms a challenge for embodiment theories claiming that this activation is both necessary and automatic for comprehension to occur.

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36.413 **Coding of Visual Stimuli for Size and Animacy** Xiaokun Xu[1](xiaokunx@usc.edu), Manan Shah[2], Irving Biederman[1,2]; [1]Department of Psychology, University of Southern California, [2]Neuroscience Program, University of Southern California

Subjects performed a verification task in which they judged whether a picture matched a preceding target word. Interest centered on negative trials where the picture could differ from the target in animacy and/or referential size. The task required processing of neither of these variables, but given a target "ELEPHANT," images that matched it in animacy (e.g., HAMSTER) or size (e.g., TANK) produced reliably longer RTs and higher error rates with the increase of a match in both size and animacy (HIPPOPOTAMUS) additive with the separate effects. The additivity is suggestive of the size coding of visual entities being independent of their animacy. Recent fMRI studies have revealed a partial overlap between maps for size (large vs. small) and animacy (animate vs. inanimate) in human occipito-temporal cortex, suggesting the possibility of separate cortical areas for coding size and animacy (Konkle et al, 2012a,b; Mahon et al., 2009, Connolly et al., 2012). A 2 (animal vs. object pictures) x 2 (large vs. small referent) block fMRI design (with an orthogonal task) found animate and inanimate stimuli differentially activated lateral and medial occipital-temporal cortex, respectively. However, separate regions coding for size were not apparent except that large, inanimate objects activated a region partially overlapping with PPA. Our results suggest that an entity's semantic features for size and animacy are automatically activated, with the size feature associated with each entity and thus distributed throughout the animate/inanimate map. The comparison of sizes, however, may be performed in a common (likely parietal) area, not associated with any category (Dehaene, 2003). Somewhat consistent with this result is Paivio's (1975) finding that judging the referential size of two images is independent of whether the entities are within vs. between superordinate (animate vs. inanimate) classes, e.g., zebra-dog vs. zebra-lamp.

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36.414 **Real-world size influences visual search efficiency** Bria Long[1](brialong@fas.harvard.edu), Talia Konkle[1], Michael A. Cohen[1], George A. Alvarez[1]; [1]Harvard University, Department of Psychology

Real-world size is an intrinsic property of objects: it is accessed automatically when we see an object and predicts a consistent medial-to-lateral organization in ventral temporal cortex (Konkle & Oliva, 2012). Is real-world size a purely abstract concept or a conceptual distinction reflected in perceptual differences? Since visual search performance is primarily determined by perceptual similarity, if big and small objects tend to be perceptually different from each other, it should be easier to find a target object among distractors with a different (vs. same) real-world size than the target. We examined visual search rates for big and small manmade objects (Experiment 1) and big and small animals (Experiment 2). The stimulus sets were matched for familiarity, typicality, aspect ratio, area, contour spikiness, object extent; gray-scale images were equalized across luminance, contrast, and power spectrum (spatial-frequency/orientation). On each trial, a target item was previewed, followed by a search display with 3 or 9 items. All items were presented at the same physical size on the screen, but the distractor items were either from the same or different real-world size category as the target. Participants pressed the space bar when they found the target, after which all items were replaced with X's and participants clicked on the target's location. In both experiments, participants were significantly more efficient at finding the target item among different real-world size distractors than among similar real-world size distractors, as indicated by faster search slopes for different-size trials (Objects: different-size slope: 51.88 ms/item, same-size slope: 61.03 ms/item, $p<.01$; Animals: different-size slope: 70.26 ms/item, same-size slope: 76.88 ms/item, $p<.05$). Because we controlled for differences in a wide range of basic feature and shape dimensions, these results suggest that real-world size is a conceptual distinction that correlates with mid/high-level perceptual features that guide visual search.

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36.415 **Hysteresis in the Perception of Objects and Scenes** Sonia Poltoratski[1](sonia.poltoratski@vanderbilt.edu), Frank Tong[1]; [1]Department of Psychology, Vanderbilt University

Recently, we have considered how categorization occurs when observers dynamically view objects and scenes (Poltoratski & Tong, VSS 2012). We developed a set of 16s 'movies' that smoothly transitioned between a single closely viewed object and the entire scene. We found that when observers made online reports of whether they perceived these movies as either predominantly 'object' or predominantly 'scene,' their responses were contingent on the direction in which the movie was shown. We found this hysteresis-like effect to be consistent across manipulations of the stimulus; herein, we sought to characterize its resilience to manipulations of observer criterion and motivation. In Experiment 1, we introduced a semantic manipulation that required observers to report either 'time as object' or 'time as scene' for each movie, rather than reporting both concurrently. This allowed us to identify periods of uncertainty, which could occur if the stimulus is not unequivocally perceived as an object or a scene. Even when accounting for uncertainty, a significant effect of hysteresis was still present (2.26s). In Experiment 2, we tested whether observers could avoid hysteresis when encouraged to do so, providing a monetary bonus for responding consistently across presentations of each movie and cumulative feedback between experimental blocks. In the first block, a typical hysteresis difference was found (3.53s). By the fifth block, participants reported using an alternative strategy to improve the consistency between their responses and ignoring the original object/scene task. We conclude that the hysteresis mechanism persists even with high motivation to respond consistently (in Block 1), but that observers can gradually learn to respond consistently by relying on alternative cognitive strategies to avoid their predisposition for hysteresis. With these two experiments, we show that the hysteresis effect for gradual transitions between objects and scenes is robust to manipulations of observer criterion and motivation.

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36.416 **Can I find my pants in the kitchen? Electrophysiological markers of categorical search using pictorial stimuli.** Rebecca Nako[1](beccanako@gmail.com), Rachel Wu[2], Tim J. Smith[1], Martin Eimer[1]; [1]Department of Psychological Sciences, Birkbeck, University of London, [2]Brain and Cognitive Sciences, University of Rochester

Understanding category structure helps us make sense of the world, but little is known about how we use our knowledge about object categories during search. This study used event-related potential (ERP) markers of attentional object selection to investigate differences between search for one or two specific visual objects and category-based search, and to explore how categorical search can overcome working memory limitations. In contrast to most previous ERP studies of visual search which used colored shapes or alphanumeric stimuli, we employed more complex pictorial images of clothing and kitchen utensils. This enabled us to examine attentional selection in a more naturalistic context where participants may try to "find the pants" amongst kitchen utensils (or vice versa). In different blocks, they searched for one single target (e.g., pants), one target that could appear in two different views (e.g., a shirt in one of two possible orientations), two different targets (e.g., either a shoe or a scarf), or a category-defined target (e.g., any of eleven different clothing items). The N2pc component (an ERP marker of attentional object selection) was measured in response to target objects. As expected, this component was largest in the single-target condition where target selection could be based on a perceptual match with a search template. Presenting a single target object from different views had little effect on the N2pc, suggesting that search was object-based rather than view-based. N2pc components were attenuated and delayed in the two-target condition and even more so for category-defined targets, reflecting search efficiency costs when target selection cannot be guided by a single-object template. However, a reliable N2pc was present even during search for one of eleven possible category-defined targets demonstrating that category-based search remained surprisingly efficient. Our results show that category-based attentional guidance is readily available during search for complex naturalistic visual objects.

36.417 **Intrinsic Structure of Visual Exemplars and Category Representations in Macaque Brain** Ning Liu[1](lning@mail.nih.gov), Nikolaus Kriegeskorte[2], Marieke Mur[2,3], Fadila Hadj-Bouziane[1], Wen-Ming Luh[4], Roger Tootell[1,5], Leslie Ungerleider[1]; [1]Laboratory of Brain and Cognition, NIMH, NIH, Bethesda, MD, [2]Cognition and Brain Sciences Unit, Medical Research Council, Cambridge, UK, [3]Department of Cognitive Neuroscience, Faculty of Psychology and Neuroscience, Maastricht University, Maastricht, The Netherlands, [4]Functional MRI Facility, NIMH, NIH, Bethesda, MD, [5]Athinoula A. Martinos Center for Biomedical Imaging, MGH, Charlestown, MA

The neural mechanisms underlying the ability to identify and categorize a wide variety of objects effortlessly have been the focus of many studies. Previous studies, especially neuroimaging ones, have typically investigated brain responses to different predefined categories without distinguishing responses to individual object exemplars. Thus, it is unclear whether the commonly defined categorical structure actually reflects the intrinsic organization of individual object representations in the brain. To answer this question, three monkeys were presented with 96 images of isolated real-world objects while they performed a fixation task in a rapid event-related fMRI experiment. Object representations were measured using fMRI and analyzed at the single-image level. We found that the multi-voxel response patterns to individual objects in the inferior temporal (IT) cortex encode the animate-inanimate categorical division, with a subordinate cluster of faces within the animate category. These results are consistent with previous results from both monkey electrophysiology and human fMRI studies, providing the missing link between those previous studies. Furthermore, we found differences in object representations between TEO and TE: individual object representations formed only an animate cluster (without any sub-clusters) in TEO, but formed both animate (with a face sub-cluster) and inanimate clusters in TE. Our findings thus support a hierarchical organization from TEO to TE in object processing. We did the same analyses in two output regions of IT cortex, namely, the amygdala and prefrontal cortex. We found the individual object representations in these two regions either did not exhibit any categorical structure or exhibited a categorical structure different from that in IT cortex. Despite the different object representations in the IT cortex, amygdala and prefrontal cortex, there were significant representational connectivities among these regions. Our findings reveal a hierarchical organization in the intrinsic structure of individual object representations and categorization in the non-human primate brain.

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36.418 **Normal body perception without the right fusiform body area** Brad Duchaine[1](bradley.c.duchaine@dartmouth.edu), Tirta Susilo[1], Hua Yang[1]; [1]Psychological and Brain Sciences, Dartmouth College

Neuroimaging studies have identified sets of cortical regions in the occipital and temporal lobes that respond much more strongly when people view particular categories such as faces, bodies, and places than other categories (Kanwisher, 2010). These areas have attracted extensive research attention, but their roles remain unclear. Here we investigate a basic question about category-selective regions: Does normal perception of a category require the functioning of all regions showing a preferential response to that category? To address this issue, we tested Galen, a 30-year-old right-handed male physician who had surgery eight years ago to remove an arteriovenous malformation in his right occipito-temporal cortex. Galen has no right fusiform body area but his other body-selective regions remain intact. To our surprise, Galen showed normal performance with all aspects of body perception tested including body detection, body shape matching, body pose matching, and body sex discrimination. Our finding demonstrates that perception of multiple aspects of a category can be normal despite the loss of a region that responds preferentially to that category.

Acknowledgement: Hitchcock Foundation

36.419 **Stimulus representations in body-selective regions of the macaque and human cortex assessed with event-related fMRI** Jan Jastorff[1](jan.jastorff@med.kuleuven.be), Ivo Popivanov[1], Natalie Caspari[1], Guy Orban[1,2], Wim Vanduffel[1,3,4], Rufin Vogels[1]; [1]Laboratorium voor Neuro- en Psychofysiologie, KU Leuven, Leuven, Belgium, [2]Department of Neurosciences, Parma University Medical School, Italy, [3]MGH Martinos Ctr., Charlestown, [4]Harvard Medical School

Functional imaging studies in humans and monkeys have shown category-selective regions in the temporal cortex, in particular for faces and bodies. However, we still know little about the functional properties of such regions and their correspondence across the two species. To address this question, we investigated the selectivity and spatial distribution of body and face patches testing an identical set of 200 stimuli in both species. We showed achromatic images of headless Monkey and Human Bodies, two sets of man-made Objects, Monkey and Human Faces, four-legged Mammals, Birds, Fruits, and Moore Sculptures to 7 human subjects and 4 macaque monkeys in an event related design. Two regions in the middle and anterior Superior Temporal Sulcus (STS) of the monkey were more strongly activated by monkey bodies compared to objects. These two regions partially overlapped with regions that were more activated by faces than objects. Multi-voxel-pattern analyses showed that both body-selective regions primarily distinguished faces from other inanimate and animate objects, including bodies. A secondary distinction was present between inanimate objects and bodies in the middle STS body region. In humans, the extrastriate body area (EBA) primarily distinguished between animate and inanimate stimuli with a secondary distinction between bodies and faces. The fusiform body area (FBA) primarily distinguished faces, animals and birds from the other categories with a secondary distinction between bodies/sculptures and the other inanimate stimuli. At the individual stimulus level, both EBA and FBA showed three main cluster, almost perfectly separating the 80 body stimuli, the 40 face stimuli and the 80 inanimate stimuli. Overall, these data indicate strong spatial clustering of animate categories in the macaque STS and human occipito-temporal cortex. Even though the clustering results were slightly different between humans and monkeys, the overall dissimilarity matrices of EBA and the mid STS body patch were highly congruent.

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36.420 **Visual categorization and identification of unattended objects: are faces unique?** Nurit Gronau[1](nuritgro@openu.ac.il), Rotem Amar[1], Anna Izoutcheev[1], Vladimir Kalendarev[1]; [1]Department of Psychology, The Open University of Israel

The extent to which visual stimuli are recognized in the absence of attention is under dispute. While several researchers have argued that real-world objects can be detected and categorized when presented at an unattended location, other have provided evidence against such 'attention-free' findings. Most studies have used dual task paradigms, in which participants perform a highly demanding task, while simultaneously detecting a pre-specified object category appearing at a peripheral location (e.g., an animal or vehicle). We sought to examine pre-attentive object processing using a different approach, in which objects are strictly irrelevant to task-requirements and to response-selection processes. In a series of studies we demonstrated that, despite its irrelevance to task demands, participants are sensitive to object categorical identity when stimuli are presented inside, but not outside the focus of visual attention. Our results suggested that when unattended objects are strictly task-irrelevant they are not automatically categorized and identified. In the present research we asked whether faces form a unique class of stimuli that can be categorized pre-attentively. Using an experimental paradigm identical to our previous research, we have obtained a 'categorical effect' for task-irrelevant faces appearing outside the main focus of visual attention, indicating that the latter are categorized involuntarily. A possible account, however, for this finding is the low interstimulus perceptual variance among facial stimuli, relative to superordinate categories such as animals and vehicles. Indeed, when examining houses, chairs, and cars, a similar categorical effect was obtained for the unattended stimuli. These findings indicate that narrow, highly distinct, categories may be benefit from automatic pre-attentive processing. Faces, then, may not be special relative to other basic-level categories. Finally, an additional set of experiments suggests that famous faces may be detected and recognized at the subordinate level even when unattended, presumably due to our extensive experience with such stimuli.

Acknowledgement: This study was supported by the Israeli Science Foundation and the Open University Research Fund.

Object recognition: Frames of reference

Sunday, May 12, 2:45 - 6:45 pm

Poster Session, Orchid Ballroom

36.421 **A comparison between mental object and viewer rotation reveals a substantial difficulty for viewer rotations greater than 90°** Thitaporn Chaisilprungraung[1](tchaisi1@jhu.edu), David Rothlein[2], Michael McCloskey[3]; [1]Department of Cognitive Science, Johns Hopkins University , [2]Department of Cognitive Science, Johns Hopkins University, [3]Department of Cognitive Science, Johns Hopkins University

In mental object rotation tasks participants imagine an object rotating, whereas in mental viewer rotation tasks the participants imagine themselves moving around an object or scene. Given that the relative motion of the participant and object is the same, do imagined object rotations involve different cognitive processes than imagined viewer rotations? In three experiments, participants performed imagined object and viewer rotations on pictures of bilaterally asymmetric objects (e.g., a hammer) presented at oblique orientations. In the first experiment, participants drew the stimulus after imagined object rotations of 0˚, 90˚CW, 90˚CCW or 180˚. In the second experiment participants drew the stimulus after imagined viewer rotations of 0˚, 90˚CW, 90˚CCW or 180˚. Analyses of errors revealed that 180˚ viewer rotations were substantially more difficult than all other object or viewer rotations. A third experiment revealed that the difficulty extended to 135˚ viewer rotations. Interestingly, the difficulty for 135˚ and 180˚ viewer rotations was observed only when the correct response orientation was oblique, and not for cardinal response orientations. We interpret these findings within a theoretical framework that characterizes both object and viewer rotations as transformations over mental representations that specify the correspondence between two reference frames.

36.422 **Environmental orientation influences novel shape learning**

Nicolas Davidenko[1](ndaviden@ucsc.edu), Stephen Flusberg[2]; [1]Department of Psychology, UC Santa Cruz, [2]Department of Psychology, SUNY Purchase

Our ability to recognize familiar objects depends in part on their visual orientation. In the most well-known case, we are better able to recognize faces when they appear upright than inverted (e.g., Yin, 1969). We recently showed that in addition to retinal orientation, environmental orientation also influences performance in face processing tasks; participants were better at perceiving and remembering faces when the faces were environmentally upright as compared to environmentally inverted, even when retinal orientation was held constant (Davidenko & Flusberg, 2012). Here we investigated whether this sensitivity to environmental orientation requires a lifetime of exposure to a class of stimuli, or whether it can manifest in a short-term learning paradigm. In an old/new recognition task, we presented participants with novel abstract 2D shapes while they lay horizontally. Between study and test, we manipulated participants' orientation (same as in study or Δ180°) and the shapes' orientation (same as in study or Δ180°). This allowed us to detect independent effects of retinal and environmental orientation on recognition performance. We found that retinal orientation significantly affected performance, with mean d'=1.29 when retinal orientation was matched between study and test versus d'=0.87 when it when it differed by 180° (t-test20=5.5, $p<0.0001$). Intriguingly, environmental orientation also affected memory performance, with d'=1.20 when environmental orientation was matched versus d'=0.95 when it differed by 180° (t-test20=3.2, $p<0.005$), consistent with early experiments by Irvin Rock (1957). In a follow-up experiment, we included sitting upright conditions to test whether environmental orientation is always represented, or only when an observer is in a non-canonical orientation during encoding. We found similar effects of environmental orientation when subjects learned the shapes while sitting upright as while lying sideways ($p>0.5$). These results suggest that environmental orientation plays a role in our visual representations regardless of our orientation during encoding.

36.423 **Relative Throw-ability of Objects of Varying Size and Weight Is Perceivable As Revealed By Magnitude Estimation Methods**

Todd Mirich[1](tmirich@uwyo.edu), Qin Zhu[1], Geoffrey Bingham[2]; [1]Division of Kinesiology and Health, University of Wyoming, [2]Department of Brain and Psychological Research, Indiana University

Introduction: Bingham et al (1989) found that throwers could perceive the optimal weights for objects of given sizes to be thrown to maximum distances. This has been confirmed numerous times (Zhu et al, 2008, 2009, 2011, 2012). Bingham et al. also speculated that the relative throw-ability among all object sizes and weights might be perceivable, but this had not been tested until now. Methods: 21 skilled throwers were blindfolded and asked to judge the throw-ability of 24 objects (3 sizes and 8 weights in each size) by hefting objects in the throwing hand. Participants were assigned randomly to one of three groups. Each group selected the optimal object in one of the sizes. The selection was used as a reference (magnitude = 100). Participants compared all remaining objects with the reference to judge relative magnitudes of throw-ability. Results: A mixed design ANOVA was performed on judged magnitudes, and no main effect was found for group, but the interactions with weight ($F_{14,126} = 3.5$, $P <0.001$) and size by weight ($F_{28,252} = 2.2$, $P <0.001$) were significant as were size ($F_{2,36} = 13.2$ $p <0.001$) and size by weight ($F_{14,252} = 21.2$ $p <0.001$). Results for COV were closely related. Post-hoc analyses showed different weights were rated highest within each size with the least variability. This pattern of judgments was similar to that in skilled long distance throwing using the same objects (Zhu & Bingham, 2008). For instance, 1'' balls were rated higher and thrown farther than 6'' ones. Heaviest weights in 1" and middleweights in 6" were rated highest and thrown farthest. Conclusion: The speculation of Bingham et al. was confirmed by the current study, which implies the general mapping from throwing performance to perception of the relevant affordance.

36.424 **Non-Retinotopic Perception: Predictions and Empirical Tests of a Reference-Frame Metric Field Theory**

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Purpose: Retinotopic representations cannot explain perception under normal viewing conditions. Recent studies have shown that processing of shape, color, motion, search, attention, and perceptual learning can take place in non-retinotopic representations. The bases of non-retinotopic representations remain largely unknown. Here, we propose and empirically test a Reference-Frame Metric Field (RFMF) theory for non-retinotopic representations. Methods: According to the RFMF theory, motion groupings in the retinotopic space generate local motion vectors with an associated reference-frame field spreading in space. Fields of different motion vectors interact. Each region in the resulting field is mapped onto a non-retinotopic representation. In order to test RFMF, we used a Ternus-Pikler display consisting of three disks and a probe dot whose perceived motion served as the dependent variable (Boi et al., 2009). The probe dot was placed inside as well as outside of the Ternus-Pikler disks and the distance of the probe dot to the disks was the independent variable. In additional experiments, two Ternus-Pikler stimuli were used to study field interactions. Results: Ternus-Pikler stimuli act as non-retinotopic reference-frames outside of their inducing disks, supporting the field prediction. Multiple Ternus-Pikler stimuli generate interacting reference frames, as one would expect from interacting fields. In contrast, static Ternus-Pikler stimuli have no effect on a field created by a dynamic Ternus-Pikler stimulus. The size of the Ternus-Pikler disks has no effect on the field strength. These results indicate that fields are generated by motion, and not by static aspects of the stimuli. We also show a novel illusion wherein the field generated by a Ternus-Pikler stimulus can cause dynamic switches in the identities of stationary stimuli creating non-retinotopic motion and invisibility effects. Conclusions: Taken together our results support the theoretical view that a field organization in the retinotopic space leads to coordinate transforms that establish non-retinotopic spacetime representations.

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36.425 **The neural correlates of non-retinotopic processing in human visual cortex: a 7T fMRI study**

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Under normal viewing conditions, due to e.g. the motion of objects, the retinotopic representation of the environment constantly changes. Yet we perceive the world as stable and we easily keep track of moving objects, indicating the presence of non-retinotopic representations in the brain. We investigated the neural correlates of such non-retinotopic processing in the human visual cortex by means of high-resolution fMRI. To this end, we used a Ternus-Pikler display: Three horizontally aligned dark/light gray checker-boards moved back and fourth in a left-right apparent motion while participants kept their gaze fixated above the stimulus, resulting in a non-retinotopic integration of the elements across frames. In a second condition, only two checker-boards were presented at the same location in each frame, thus causing the elements to be integrated retinotopically. Crucially, the checker-boards could be either flickering, i.e. inverting polarity with each frame, or non-flickering. This retinotopic flickering or non-flickering is perceived in the 2-element conditions. In the 3-element conditions, however, because of the non-retinotopic correspondence, the percept is inverted such that the non-flickering checker-boards are perceived to flicker and vice versa. In V1, we found a higher BOLD response for retinotopically flickering stimuli, as expected, but the activity did not depend on the percept of flickering vs. non-flickering. In hMT+ we found a stronger response for the 3-element conditions, which could be due to the apparent motion as well as the larger size of the stimuli. More interestingly, there was also an interaction effect, namely higher activity for perceived flickering than perceived non-flickering. Thus, apart from the retinotopic properties of the stimuli, also the endogenous percept of non-retinotopic origin is reflected in the hMT+ activity.

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Visual search: Spatial and temporal aspects

Sunday, May 12, 2:45 - 6:45 pm

Poster Session, Orchid Ballroom

36.426 Visual Searches Need Their Own Personal Space: The Importance of Spacing Between Simultaneously Presented Search Arrays.

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Visual search, the process of looking for targets amongst distractors, is an everyday activity executed in a variety of contexts. While searches are often mundane (e.g., looking for your keys) they can also be highly important (e.g., airport baggage screeners looking for contraband). Considerable research has examined the nature of visual search accuracy, but how well do the results generalize to real-world visual searches? For example, most cognitive psychology experiments present observers with a single search array and assess how quickly and accurately target(s) are found. However, airport baggage screeners often view displays that contain multiple search arrays (i.e., several bags on the same x-ray monitor), and these search arrays can be close together and/or appear physically connected (e.g., when passengers shove their bags into the x-ray machine). Here we investigated how accuracy is affected when multiple search arrays are simultaneously present, and whether spacing between arrays impacts performance. Experiment 1 presented 3 search arrays, either spaced close together (5-pixel separation) or far apart (100-pixel separation), and each array could contain 0, 1, or 2 targets. Trials progressed by having the arrays physically shift to the edge of the monitor as if on a conveyor belt, and participants were to only search the center array before advancing. Array spacing did not impact response time or accuracy on single- and no-target trials, but did affect dual-target trials: second target accuracy (after having found a first target in the same array) was significantly worse when the arrays were close together than far apart. Experiment 2 compared trials with 3 far-spaced arrays to trials with only a single array, and there were no response time or accuracy differences. Collectively, the results suggest that search array spacing can negatively impact accuracy for dual-target search, which is a particularly complex search process.

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36.427 Perceptual exposure does not alter advantage for familiar brand logos in visual search

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Familiarity often benefits visual search. We previously found that familiar brand logos (e.g., Coke) were searched for faster and more efficiently than less familiar logos (e.g., Mello-Yello). Can such familiarity be created in the lab? We explored this question in 7 experiments, with different perceptual familiarization tasks. Subjects were trained on 10 unfamiliar logos that served as target items in a visual search task. Other targets included 10 untrained unfamiliar logos and 20 pre-experimentally familiar logos. All distractor logos in search displays were unfamiliar. To minimize memory demands, subjects were cued on each trial with the image of a target, which remained present throughout the trial. Search set sizes were 3, 6, or 9 logos. In Experiments 1-3, an N-back-like familiarization task was used, in which subjects monitored sequences of logos for repetitions. In Experiments 4 and 5, subjects answered 14 questions about perceptual details (e.g., shape, color) of each unfamiliar logo. In Experiments 6 and 7, subjects were trained with the 14 questions on two separate days. In all 7 experiments, pre-experimentally familiar target logos were searched for faster than unfamiliar untrained logos (all overall RT differences $p < 0.001$) with significantly shallower slopes relating RT to number of items in the display ($p < 0.05$ in 6 of the 7 experiments). However, perceptual familiarization did not facilitate overall search speed for initially unfamiliar logos (RT differences $p > 0.05$, except in Experiment 3, $p = 0.041$) or change search slopes ($p > 0.05$ in all experiments). We conclude that logo familiarity is a robust phenomenon that cannot be easily obtained through laboratory perceptual training. The visual benefits of familiarity with everyday objects, such as brand logos, may depend upon experience in more elaborated contexts that support semantic processing.

36.428 Effects of Foveation on Visual Search Task with Visual Prosthesis Simulation

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A visual prosthesis simulator with capabilities to simulate several retinal diseases including Retinitis Pigmentosa (RP) and Age-Related Macular Degeneration (AMD), as well as a visual representation of prosthetic vision, was constructed to simulate both eye-directed and head-directed percepts using normally sighted volunteers wearing a head-mounted display with an external scene camera. These head and eye pointed modes allow the effects of foveation in retinal prostheses to be studied. Visual search experiments are a recognized method to quantify the efficiency by which a subject can visually locate and recognize a target object, and have shown that normally sighted subjects exhibit a strong linear relationship between the response time to locate a target object and the number of total distractor objects displayed. The present study compared normal visual search results to both head-pointed and eye-pointed (simulated) retinal prostheses. Four subjects performed a visual search task with black letters on a white screen spanning a 90° field of view while wearing the visual prosthesis simulator in both head-pointed and eye-pointed camera modes. In both simulation modes, the percept was stabilized on the subject's retina using an eye-tracker. The letter "F" was used as a target object with letter "E" distractor objects also present. Letter size was adjusted to be well above the visual acuity limit during simulation of AMD with a 32 × 32 retinal prosthesis electrode array. Response time to find the target was plotted against the number of distractors for both head-pointed and eye-pointed camera modes, and compared to unrestricted normal vision trials without the use of the simulator. All subjects showed a significant linear trend in the response time plots. In each case, the slopes and intercepts of the linear regressions are significantly lower in the eye-pointed case than in the head-pointed case, suggesting an overall improvement in function.

Acknowledgement: National Science Foundation, National Science Foundation Graduate Research Fellowship

36.429 The effect of task difficulty on visual search strategy

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In a test of their DMS-model (Difficulty Moulds Search), Young and Hulleman (JEP:HPP in-press) showed that the Functional Visual Field (FVF) in visual search becomes progressively smaller when task difficulty increases from easy (/ amongst |), via medium (T amongst Ls), to hard (notched square amongst rotated notched squares). Here, we report eye movement data illustrating how task difficulty also shapes search strategy. First fixation durations in unrestricted search scaled with task difficulty. They were much longer for easy search (375-476 ms) than for medium (321-367 ms) and difficult search (263-300 ms). A gaze-contingent window experiment confirmed that this was due to FVF-size. Importantly, saccadic amplitude not only depended on task difficulty (cf. Rayner, 2009), but also on target presence and number of preceding saccades. In easy search, saccadic amplitudes for absent trials gradually increased (from 6 degrees for early to 10 degrees for later saccades), but for present trials they progressively decreased (from 6 down to 2 degrees). Though less pronounced, medium difficulty search showed the same pattern (rising from 5 to 8 degrees and falling from 5 to 4 degrees). For difficult search, saccadic amplitude (about 5 degrees) was essentially independent of both target presence and rank number. These results concur with the DMS-model and provide new insights into how task difficulty determines search strategy. In easy search, the large FVF allows most work to get done in a long duration first fixation, resulting in a rapid zooming in target-present trials. When no target is present, ever larger saccades are made to cover the entire display. In very difficult search the small FVF does not permit processing of large parts of the display in the opening fixation, resulting in shortened first fixation durations and subsequent item-by-item fixations without any idea whether the next item is the target.

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36.430 **Is an Image Worth a Phonological Representation? Investigating the effect of target-distractor phonological similarity in multiple-target search** Stephen Walenchok[1](swalench@asu.edu), Michael Hout[1], Stephen Goldinger[1]; [1]Arizona State University

When people perform visual search, a target "template" is used to guide attention to the location of the target. Such templates typically contain visual information, but what role might linguistic information play in creating representations of to-be-located items? For instance, maintaining visual information about a single target is easy, but when people look for multiple targets, might they rely upon less demanding, verbal codes? We investigated this question by comparing visual and phonological competition effects in visual search. In different displays, participants searched for visual targets among visually similar distractors or searched for visual targets among phonologically similar distractors. In the latter case, targets and distractors shared phonological onsets (e. g., "banjo" and "bucket"). In both cases, search was compared to control displays, either with uniformly dissimilar or random controls. Visual competition effects were robust; finding a baseball among other orb-shaped distractors was difficult, relative to rectangular or randomly mixed distractors. Phonological similarity effects were more challenging to observe: In Experiment 1, we used a standard visual search task, varying target load (single versus multiple-target search) and template versus categorical-search. We expected participants to rely more upon verbal search templates during multiple-target search, and when words were used to define targets. Nonetheless, the results revealed strong effects of visual, but not phonological, interference in all conditions. In Experiment 2, we intensified the phonological similarity among depicted objects, with greater overlap among object names (e. g., "bean" and "beaver"). In this case, we did observe phonological interference effects in both template and categorical search conditions, especially in multiple-target search. The results suggest that verbal codes may be active in visual search, but that their use is not ubiquitous.

36.431 **Does the direction of dimensional changes influence reaction time costs in visual search?** Sandra Utz[1](Sandra.Utz@uni-bamberg.de), Claus Christian Carbon[1]; [1]Department of General Psychology & Methodology, University of Bamberg

In traditional visual search experiments, participants are required to detect the presence of a predefined target item (e.g., a red bar) surrounded by varying numbers of irrelevant distractor items (e.g., green bars). Müller and his colleagues (e.g., Müller, Heller, Ziegler, 1995) observed that reaction times (RTs) are significantly faster when the target was defined within the same dimension in consecutive trials (e.g., red -> red; red ->green) compared to when the dimension of the target changed (e.g., red -> left-tilted). Aim of this study was to systematically investigate if the direction of dimensional changes plays a significant role in RT costs to develop a model of RT prediction under such conditions, which also comprises specific RT costs for dimension changes from color to orientation vs. orientation to color. 11 participants had to search for targets defined by either their color (red or blue) or orientation (right- or left-tilted) and the target dimension either stayed the same or changed on consecutive trials. Results showed the typical results pattern of remarkably higher RTs in dimensional change conditions (M = 470.4ms; SD = 49.6ms) in comparison to within dimensional conditions (M = 417.5ms; SD = 37.0ms; $t(10) = -7.87$; $p < .001$, $d = 2.37$). The closer look to the dimensional change trials revealed significantly higher RT costs if the change was from a target defined in the color dimension to a target defined in the orientation dimension in comparison to a change from orientation to color ($t(10) = 2.32$; $p = .04$, $d = .71$). A possibly stronger pre-activation of the color dimension and differences in the time necessary for shifting the attentional focus from color to orientation or from orientation to color could explain our results. Further experiments will have to extend the used paradigm by integrating further dimensions such as size, to reveal further asymmetries in RT costs.

36.432 **Visual Search Efficiency for Features in Chernoff Faces** Navaneethan Siva[1](nxsivagnanasundaram@wichita.edu), Alex Chaparro[1], Duy Nguyen[1], Evan Palmer[1]; [1]Psychology, College of Liberal Arts and Sciences, Wichita State University

Chernoff faces (Chernoff, 1973) graphically depict multidimensional data by correlating features of a cartoon face with values from a data set. Chernoff's original motivation for their use was that people perceptually prioritize faces and are acutely aware of variations in facial expression, so mapping data onto faces would support better understanding of complex data sets. Chernoff faces are usually depicted in groups where each face represents one particular case or unit and are compared to represent an entire dataset and its relationships. In this study, the authors sought to identify: i) the efficiency of visual search through sets of Chernoff faces relative to extant visual search efficiency benchmarks (e.g., spatial configuration search efficiency), ii) if face recognition processes do indeed provide advantages in visual search for such data, and iii) whether some facial features support more efficient search than others. The study consisted of four conditions in which two sets of four Chernoff faces were compared, each differing from a neutral face by one feature, for both upright and inverted versions. Inverting faces is known to interfere with face processing (e.g., Yin, 1969), so if face processing provides an advantage in searching through Chernoff faces, we reasoned that inverting the stimuli should slow search. The task was an oddball search with unlimited display durations and response time as the major dependent variable. Participants reported whether they saw a target face that differed from the neutral faces on each trial. Set sizes 5, 10 and 15 were tested, with target trials occurring 50 percent of the time. Results indicate differences in search efficiency for the various features, with particularly slow search for eyebrow position. Additionally, there was no observable effect of face inversion on search efficiency, for either set of facial features.

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36.433 **Is search over time functionally equivalent to search over space?** Nicole L. Jardine[1](nicole-jardine@uiowa.edu), Cathleen M. Moore[1]; [1]Department of Psychology, University of Iowa

Most visual search experiments use static scenes, but most visual search involves scenes that change over time. We have investigated the consequences of dynamics on the ability to perform orientation search (e.g., VSS 2011). Search for a tilted bar among non-tilted bars displayed for 200 ms is highly accurate when this display is presented in isolation, but extremely difficult when the same display is part of a 3-frame movie of rotating bars (Exp. 1). A 3-frame movie has three times the number of distractors, and we know that increased target-distractor similarity in static displays can cause search inefficiency. Is search over time analogous to searching the same stimuli over space? Exp. 2a and 2b showed that when all stimuli from the dynamic display were presented in the same frame (removing temporal aspects), search was as difficult as when the stimuli were presented in the dynamic series of frames. This suggests that the representations of features from the changing scenes remain active for some time within the representation used in temporal search. Dynamic search can, however, benefit from spatial consistency and motion coherence. When the stimuli were presented over time as in the original dynamic displays, but the stimuli were repositioned in each frame, search was more difficult than with the original dynamic displays in which stimuli were in the same locations across frames (Exp. 3). And when spatial consistency was maintained but the order of frames was shuffled, performance was worse than with the original coherently changing dynamic displays (Exp. 4). Thus although dynamic search appears to be similar to search within a static ensemble that contains all of the information from across the dynamic display, dynamic search nonetheless benefits from spatial consistency and motion coherence.

Acknowledgement: NJ supported by NSF GRF 1048957. CM supported by NSF BCS-0818536

36.434 **Parallel Processing in Difficult Visual Search in both Noisy and Noiseless Displays** Richard S. Hetley[1](rhetley@uci.edu), Barbara Anne Dosher[1], Zhong-Lin Lu[2]; [1]Memory, Attention and Perception Laboratory (MAPL), Department of Cognitive Sciences and Institute of Mathematical Behavioral Sciences, University of California, Irvine, [2]Laboratory of Brain Processes (LOBES), Department of Psychology, The Ohio State University

Visual search accuracy in time-limited displays often shows a set size effect, decreasing as the number of distractors increases. This is especially so for difficult visual searches, e.g., searching for an O among C's. Original models proposed a serial search processing architecture for difficult search (Treisman & Gelade, 1980, and many others), but a growing body of evidence shows an unlimited-capacity parallel probabilistic model provides a better account of the time course of visual search in the absence of external visual noise (for time-limited displays) (Dosher, Han, & Lu, 2004; Dosher, Han, & Lu, 2010; McElree & Carrasco, 1999). Because spatial attention has been shown primarily to exclude external noise (Dosher & Lu, 2001), the current experiment tested whether a parallel probabilistic model (PPM) of search dynamics also accounts for visual search in external (masking) noise, or whether external noise induces different processing demands with capacity limits. We performed a visual search task for an O among C's in a cued-response speed-accuracy experiment, manipulating set size (2, 4, and 8), delay to the response cue (0.05 s through 1.8 s) and the presence or absence of external noise; accuracy, d', was measured as a function of processing time. Stimulus contrasts (100% and 30% contrast) were set to approximately equate overall asymptotic discrimination in the

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presence and absence of external noise. In the PPM, the probability of hits and false alarms at different processing times (and therefore d') depends on the independent finishing times of processing for all items simultaneously, while requiring different decision criteria for each set size. For all observers and conditions, the unlimited-capacity PPM provided an excellent account of both time course and asymptotic accuracy. External noise does not alter the dynamics of information accumulation in visual search.

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36.435 Hide and Seek: Searching for Poorly Defined Camouflaged Targets

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Visual search in the real world often involves locating objects that blend in with the surrounding environment. In extreme cases, such as when the search target is intentionally camouflaged, observers might seek small background discontinuities, as opposed to discrete objects, to indicate a target's presence. In two experiments, we characterized search behavior under these conditions by having participants search for a target discontinuity in natural forest scenes. Importantly, the targets were created directly from a portion of each corresponding background image, creating a camouflaged target. In Experiment 1, participants searched for randomly placed target discontinuities of varying sizes (40, 50, 60, and 70 pixel diameters). In all trials, participants received a 1s preview of the target prior to searching. Reaction times were fastest at the largest target size (~5.4s) and slowest at the smallest size (~7.3s), indicating that search became more difficult as target size decreased. Success rates in target present trials followed a similar pattern (~86% in the largest target size and ~78% in the smallest target size). Interestingly, fixation durations did not differ significantly across target sizes, indicating that information was extracted from the scene at a similar rate regardless of target difficulty. In Experiment 2, we examined whether search for discontinuities was affected by the availability of a visual target template by eliminating the target preview; observers were instructed to simply search for a camouflaged target in the background. The data were broadly consistent with Experiment 1 (reaction times of ~5.6s and ~7.1s in the largest and smallest target sizes, respectively). Overall, our data suggest that the human visual system is proficient at searching for targets that are not discrete objects. Additionally, when searching for camouflaged targets, observers are able to locate environment inconsistencies without a perfect visual representation of the target.

36.436 Global – Not Local – Variance Impacts Search

Steve Haroz[1](sharoz@ucdavis.edu), David Whitney[2]; [1]University of California at Davis, [2]University of California at Berkeley

When searching for an oddball target, how does the amount of visual variety (e.g. number of colors) immediately surrounding the target impact performance? We found that variance in the whole scene rather than just the local region matters. Subjects saw a display with 64 objects. On half of the trials, one object was given a unique visual property (e.g. one red target among many blue and green objects). The possible visual features that distinguished the objects included color, shape, or motion. Each feature had its own block of trials, so subjects knew which visual feature would contain the oddball. Subjects responded whether the target was present or absent (actually present 50%), and reaction time was recorded. Increasing the number of variants within the visual feature (e.g., going from red and blue to red, blue, green, and yellow) throughout the display (global variance) significantly impacted performance. However, increasing the number of variants immediately surrounding the target (local variance) – while keeping the global variance constant – showed no significant effect. Therefore, goal-directed or guided visual search appears to be susceptible to global display variance (how many distractor categories there are, and whether they are grouped) but is not sensitive to the local variance around the target itself.

36.437 Contextual cueing in patients with age-related macular degeneration

Franziska Geringswald[1](franziska.geringswald@ovgu.de), Anne Herbik[2], Michael Hoffmann[2], Stefan Pollmann[1,3]; [1]Department of Experimental Psychology, Otto-von-Guericke-University Magdeburg, Magdeburg, Germany, [2]Visual Processing Laboratory, Ophthalmic Department, Otto-von-Guericke-University, Magdeburg, Germany, [3]Center for Behavioral Brain Sciences, Magdeburg, Germany

Visual attention can be guided by past experience of regularities in our visual environment. In the contextual cueing paradigm (Chun & Jiang, Cogn. Psychol. 36, 28–71, 1998), incidental learning of repeated distractor configurations speeds up response times compared to random search arrays. Concomitantly, fewer fixations and more direct scan paths indicate more efficient visual exploration in repeated search arrays (Manginelli and Pollmann, Psychol. Res. 73, 212–221, 2009). In previous work, we found that simulating a central scotoma in healthy observers eliminated this search facilitation (Geringswald, Baumgartner & Pollmann, Front. Hum. Neurosci. 6, 134, 2012), likely due to a more top-down controlled exploration of the search displays. Here, we investigated contextual cueing in patients with age-related macular degeneration (AMD) who suffer from impaired foveal vision and may show a similar lack of contextual cueing. AMD patients performed visual search using only their more severely impaired eye (n=13) as well as under binocular viewing (n=16). Patient data were compared to sex- and age-matched controls who searched in perceptually more demanding displays equalizing search difficulty. Controls developed a significant contextual cueing effect. In comparison, patients' monocular as well as binocular search showed only a small but non-significant advantage for repeated displays. Number of fixations and scan pattern ratios showed a comparable pattern as search times. However, contextual cueing was significantly correlated with acuity. Thus, contextual cueing was not observed in AMD patients as a group, but it depended on acuity in that mild cases benefited more from context cues. A deficit of foveal vision appears to interfere with the implicit guidance of attention by contextual cues. This may be caused by a more top-down controlled exploration that interferes with a more bottom-up driven exploration that uses implicit memory cues (Lleras and von Muehlenen, Spat. Vis. 17, 465–482, 2004).

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36.438 I still haven't found what you're looking for: Searching for myself and then searching for you too

Michael Dodd[1](mdodd2@unl.edu), Mark Mills[1], Gerald McDonnell[1]; [1]Department of Psychology, University of Nebraska - Lincoln

Numerous factors impact attentional allocation, with behavior being influenced by both individual intent and our visual environment. As such, attention research often focuses on how attention can be made to operate more efficiently. In the present study, we investigate the influence of joint search behavior on reaction time, accuracy, and oculomotor kinematics. Within the present context, joint search occurs when one individual controls the visual input of a second individual via a gaze contingent window (e.g. participant 1 controls the window via their eye movements and participant 2—in an adjoining room—sees only the stimuli that participant 1 is directly fixating). In Experiment 1, pairs of participants complete three blocks of a discrimination task (target present/absent) which required them to either 1) Search and perform the discrimination task individually, 2) Search the display while their partner performs the discrimination task, or 3) Perform the discrimination task while their partner searches. Critically, visual search is most efficient (e.g., highest accuracy with minimal search speed reduction) when the person performing the discrimination task is doing so for the second time while the person controlling the visual output is searching for the first time. Performance is least efficient when the person performing the discrimination task is doing so for the first time while the person controlling the visual output is searching for the second time. In two subsequent experiments, task difficulty is enhanced to determine the generality of this effect. This paradigm creates a counterintuitive speed/accuracy tradeoff which combines the heightened ability that comes from task experience (discrimination task) with the slower performance times associated with a novel task (initial search) to create a potentially more efficient method of visual search. As such, the present paradigm has important practical applications to events outside the laboratory, such as x-ray screening at airport terminals.

36.439 The effects of searching for something you love (or hate): Duke and UNC students search for rival team logos.

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As the visual world is too complicated to be processed in its entirety, it is important to understand why attention is guided to some aspects of a display, but not others. The study of attentional guidance has typically focused on two distinct classes of mechanisms: stimulus-driven (the physical properties of a visual display) and goal-driven (top-down intentions). However, there are aspects not addressed by this dichotomy (Awh, Belopolsky, & Theeuwes, 2012), and perhaps the most prominent is how an observer's unique experiences and beliefs influence attentional allocation. Here, we examined "observer-driven" factors in visual search by testing observers from both Duke University and the University of North Carolina (UNC)—two schools with a long-standing sports rivalry. Participants included in the study were those who self-identified as fans of their own university and as strongly disliking the other university, and the question was whether these affiliations would affect attentional allocation. Participants completed a visual search task wherein they reported the presence or absence of one of three possible targets: the Duke logo, the UNC logo, or a familiar neutral logo (Georgia Tech). This design minimizes stimulus-driven differences as the same physical logos can engender different affective responses depending on the observers' affiliations. When searching through arrays of unfamiliar team logos, the Duke and UNC participants were quicker to find both the Duke and UNC logos than the Georgia Tech logo. Moreover, the strength of the observers' feelings towards Duke and UNC significantly affected their search efficiency—more extreme feelings (either positive or negative) produced shallower search slopes. These findings support a role for observer-driven differences in attentional allocation that goes beyond the traditional stimulus-driven versus goal-driven dichotomy.

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36.440 **Adaptive group integration rules in a signal detection task**
Mordechai Z. Juni[1](mjuni@nyu.edu), Miguel P. Eckstein[1]; [1]University of California, Santa Barbara

Previous studies on collective decision-making have investigated what rules of integration people adopt, and whether the group's collective performance outperforms each member's individual performance. Here we explore whether groups could beneficially adapt their perceptual integration rule when necessary. Triads participating simultaneously on separate computers were challenged to detect a Gaussian signal (SD=0.5 DVA) embedded in white noise (signal present 50% of the time), both individually and collectively. On each of 400 trials, participants first recorded and announced their personal ratings as to whether the signal was absent (1, 2, 3, 4, 5) or present (6, 7, 8, 9, 10). Next, they freely discussed what their collective rating should be (given their individual ratings) until they agreed upon a group rating. Finally, feedback was provided as to whether the signal was present on that trial. During the first 200 trials, the signal (when present) had 2% contrast on all three computers. During the last 200 trials, the signal (when present) had 0.5% contrast on two computers (randomized on each trial) and 9% contrast on the remaining computer. While all participants (nine in total) noticed that the signal was occasionally quite strong during the second half of the experiment, none of them reported realizing (upon subsequent questioning) that the three members of the group were being shown signals of different strengths during the second half. Nevertheless, while initially the group ratings were more correlated with an average rating rule ($p < .05$ for all three groups), they slowly adapted during the second half until finally, during the last 100 trials, the group ratings were more correlated with a more optimal rule approximated by a follow the most extreme rating rule ($p < .05$ for all three groups). This indicates that groups flexibly adopt different perceptual integration rules to improve collective performance.

36.441 **How long does it take to create a solid target template in visual search?** Junha Chang[1](junha.chang88@gmail.com), Joo-Seok Hyun[1]; [1]Department of Psychology, Chung-Ang University, Seoul, South Korea

We often search for a target object made of more than one single feature, and this supposedly requires storage of solid and bound representations of multiple features in memory. How long does it take then to form such a cohesive representation of a search target? In this study, we attempted to estimate the time necessary for forming a reliable representation of a multi-feature target by varying the delay of search array onset after designating the target feature(s). In both simple- and conjunction-feature search blocks, the target feature(s) was designated by sequentially displaying two items, and each item can possess either of two target features (e.g., color or orientation). Following after the blockwise designation of the target feature(s), the search array was displayed with randomly-chosen one of three different onset delays of 50, 500 and 1500ms. In the simple-feature search condition, the search array was made only of a target feature informed in the block, supposedly preventing the use of the other irrelevant target feature. Whereas in the conjunction-feature search condition, the search array was made of both features according to the way a conventional conjunction search array is constructed. The results showed that search RTs from the simple-feature condition were constant regardless of the onset delays of search array, but were relatively slower than the RTs from the conjunction-search condition. Such advantage in the conjunction-search condition was observed only if the onset delay of the search array was longer than 500ms. The results indicate that forming a durable target template in visual search requires a bit of time, and further suggest that on a special occasion, searching for a target consisting of multiple features can lead to faster search performance than searching for a target with a single feature if enough time to form a solid target representation is provided.

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36.442 **The contents of the search template for naturalistic visual search** Reshanne Reeder[1](reshannerae.reeder@unitn.it), Marius Peelen[1]; [1]Center for Mind/Brain Sciences, University of Trento, 38068 Rovereto, Italy

Visual search involves the matching of visual input to a "search template" – an internal representation of task-relevant information. The present study investigated the contents of the search template during naturalistic visual search, for which low-level features do not reliably distinguish targets from non-targets. Participants were cued to detect people or cars in diverse photographs of real-world scenes. On a subset of trials, the cue was followed by task-irrelevant stimuli in place of scenes, directly followed by a dot that participants were instructed to detect. We hypothesized that stimuli that matched the active search template would capture attention, resulting in faster detection of the dot when presented at the location of a template-matching stimulus. Results revealed attentional capture for silhouettes, but not surface features (color and texture), of the cued category. Silhouettes captured attention irrespective of their orientation (0°, 90°, or 180°). Interestingly, strong capture was observed for silhouettes of category-diagnostic object parts, such as the wheel of a car. Finally, attentional capture was also observed for silhouettes presented at task-irrelevant locations. Together, these results indicate that search for object categories in real-world scenes is mediated by spatially global search templates that consist of view-invariant shape representations of category-diagnostic object parts.

Motion: Optic flow

Sunday, May 12, 2:45 - 6:45 pm
Poster Session, Orchid Ballroom

36.443 **Speed tuning of optic flow parsing** Andrew J. Foulkes[1](andrew.foulkes@manchester.ac.uk), Simon K. Rushton[2], Paul A. Warren[1]; [1]School of Psychological Science, University of Manchester, UK, [2]School of Psychology, Cardiff University, UK

In order to isolate scene-relative object movement the brain attempts to perform a global subtraction of the optic flow components associated with self movement (Rushton & Warren, Current Biology, 2005). Foulkes et al. (VSS, 2012) provided evidence that this flow parsing mechanism shares some common processing stages with heading mechanisms, suggesting that heading models might provide a starting point for models of the flow parsing process. However, common heading models are speed invariant (they recover direction but not speed of observer movement). Here we investigate speed tuning for the flow parsing mechanism. Stationary participants fixated the centre of a radial flow field (30 degrees FOV) of limited lifetime dots simulating forwards motion of the observer at 0.6 m/s. Median onscreen speed was approximately 2.15 deg/s. Participants judged the direction of motion of a laterally displaced probe moving vertically upwards. To limit the contribution of local motion processing mechanisms, no flow field dots were presented in a patch of radius 3 deg centred on the probe. We manipulated the dot speed by scaling the simulated observer speed by factors of (0.25, 0.5, 1.0, 2.0, 4.0, 8.0). Participants indicated the perceived trajectory of probe motion by setting the orientation of an adjustable paddle. The relative tilt effect (difference between perceived and actual trajectory) was measured. Flow parsing predicts that the relative tilt should be inwards due to subtraction of the outwards radial flow. Results indicate a clear dependence of the relative tilt effect on simulated speed. As speed increases, the relative tilt effect also increases. However, at intermediate speeds the effect stabilises and there is a suggestion of a decrease in relative tilt for the fastest speeds tested. These results suggest that the speed invariance of common heading models makes them inappropriate to underpin models of flow parsing.

Acknowledgement: Wellcome Trust

36.444 **Characteristics of the optic flow parsing mechanism for different simulated observer movements** Paul A. Warren[1](Paul.Warren@manchester.ac.uk), Simon K. Rushton[2], Andrew J. Foulkes[1]; [1]School of Psychological Sciences, University of Manchester, UK, [2]School of Psychology, Cardiff University, UK

We have proposed (Rushton & Warren, Current Biology, 2005) and provided evidence for (Warren & Rushton, Current Biology, 2009) the existence of a global motion processing mechanism which acts to subtract out

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optic flow components. We suggest that this flow parsing mechanism helps moving observers to assess scene-relative object movement. Previously we have investigated the relative contributions of global (flow parsing) and local (e.g. motion contrast) mechanisms to perceived object trajectory. Here we assess whether the relative contributions are invariant for different simulated observer movements. The basic optic flow stimuli simulated forwards translation (1.2 m/s), yaw eye rotation (4.3 deg/s), or head/eye roll about the line of sight (23.2°/s). Median onscreen speed was matched at 4.3 deg/s for all three stimuli. Participants fixated at the centre of the display and judged the direction of motion of a laterally displaced probe. We systematically restricted the portion of the flow field available to the observer. In the "local" and "global" conditions respectively, only the flow inside and outside a circle of radius 3 degrees surrounding the probe was presented. Participants indicated the perceived probe trajectory by setting the orientation of an adjustable paddle. The relative tilt effect (difference between perceived and actual trajectory) was measured. The effect in the global condition was attributed to the flow parsing mechanism whereas that seen in the local condition was attributed to motion contrast. Average relative tilt ratios (local/global) were similar across movement types: 0.81 (forwards translation), 0.83 (horizontal rotation), 0.73 (roll). We also found evidence for a strong correlation between ratios for forwards translation and yaw ($R^2 = 0.55$) but considerably weaker correlations between roll and either of the other two movement types ($R^2 < 0.11$). These data suggest roll motion may involve different processing from translation and yaw movements.

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36.445 Perception of smooth and perturbed vection in short-duration microgravity Ramy Kirollos[1](ramyk1@cse.yorku.ca), Robert Allison[1], James Zacher[1], Pearl Gutterman[1], Stephen Palmisano[2]; [1]Centre for Vision Research, York University, [2]School of Psychology, University of Wollongong

Adaptation to the microgravity environment and readaptation to the 1-g environment requires recalibration of the visual and vestibular signals. Previous research on the perception of visually stimulated self-motion (vection) in 1-g environments has shown that adding simulated view-point oscillation enhances the illusion of self-motion. However the role simulated oscillation plays in vection in relation to adaptation to gravity remains unclear. The goal of this experiment was to understand how simulated viewpoint oscillation can change the subjective feeling of vection in microgravity compared to 1-g. This was done by measuring participant sensation of vection before, during, and after parabolic flight. Eight participants viewed twenty-second clips displayed on a thirteen-inch laptop equipped with a hood and shroud aboard the aircraft. The clips simulated vection in the radial, oscillation or jitter motion conditions and were presented during microgravity periods of the six parabolas of a flight. Participants were asked to rate their feeling of self-motion after each clip presentation. Onset of vection and vection duration were also measured by pressing a button on a gamepad during vection. Results in microgravity showed that this oscillation effect is reduced and a small overall reduction in vection sensitivity post-flight was observed. A supplementary ground experiment demonstrated that vection did not vary significantly over multiple testing sessions and that the oscillation effect persisted as previously reported in the literature. These findings: (i) demonstrate that the oscillation advantage for vection is very stable and repeatable during 1-g conditions and (ii) imply that adaptation or conditioned responses played a role in the post-flight vection reductions. The effects observed in microgravity are discussed in terms of the ecology of terrestrial locomotion and the nature of movement in microgravity.

Acknowledgement: Canadian Space Agency

36.446 Spontaneous postural instability predicts susceptibility to smooth vection Stephen Palmisano[1](stephenp@uow.edu.au), Deborah Apthorp[1], Takeharu Seno[2], Paul Stapley[3]; [1]School of Psychology, University of Wollongong, Australia, [2]Institute for Advanced Study, Kyushu University, Japan, [3]School of Health Sciences, University of Wollongong, Australia

Do individual differences with regard to the weighting of vision in the control of postural stability help identify persons who are more or less susceptible to vection (visual illusions of self-motion)? In this experiment, we measured the postural sway of standing subjects by quantifying the excursions of their center of foot pressure (CoP). Prior to exposing them to any optic flow, we measured their spontaneous postural sway with eyes open and eyes closed (CoP changes over 60-s periods were converted into sway path estimates). Subjects were then shown two types of optic flow: radially expanding optic flow (simulating constant velocity forwards self-motion) and vertically oscillating radially expanding optic flow (simulating constant velocity forwards self-motion combined with vertical head oscillation). These computer-generated displays, which subtended a visual angle of 66 deg x 62 deg, were rear projected onto a flat screen 0.65 m in front of subjects. As expected, adding simulated vertical viewpoint oscillation significantly increased the vection induced by radially expanding flow. We found that greater differences between spontaneous sway with eyes open and eyes closed significantly predicted higher vection strength ratings for purely radial flow, but not for vertically oscillating flow. Thus, it appears that the importance of vision for postural stability predicts vection strength for displays which represent smooth self-motion, but for oscillating displays, other factors, such as visual-vestibular interactions, may be more important.

Acknowledgement: ARC DP1093493

36.447 Combining depth and motion to detect moving objects in an optic flow field Constance Royden[1](croyden@mathcs.holycross.edu), Laura Webber[1], Sean Sannicandro[1]; [1]Department of Mathematics and Computer Science, College of the Holy Cross

When an observer translates through a stationary scene, the object images move in a radial pattern. Theoretically, one can identify moving objects by finding regions in which the image velocities differ in direction or speed from the radial flow field. A computational model that performs motion subtraction, similar to the neural responses in cortical area MT, can identify moving objects using these direction and speed cues (Royden & Holloway, 2009). However, speed is an ambiguous cue, because an increase (or decrease) in speed could arise from motion of an object or from a decrease (or increase) in the object's distance from the observer, causing the model to identify stationary objects as moving. Adding stereo information allows one to distinguish between these possibilities. We added stereo tuning, similar to that seen in MT cells, to the model and tested the model's ability to distinguish between stationary and moving objects for a moving observer. We simulated observer motion toward a frontoparallel plane of random dots positioned 1000 cm from the observer. The scene contained two square objects, one static and one moving laterally at 12 deg/sec. Observer speed was 200 cm/sec with a heading of (0,0). We tested simulated fixation distances of 250, 550 and 850 cm, and object distances of 250, 300, 350, 550 and 850 cm. For object distances of 300 cm and above, on average the model identified 0.67 out of 12 border positions on the static object and 10.5 out of 12 for the moving object. For an object position of 250 cm, the model incorrectly identified the stationary object as moving. Thus, except for the condition with the fastest image speed for the object, the addition of stereo tuning enabled the model to distinguish between moving and stationary objects for a moving observer.

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36.448 Effect of Local Motion Averaging on the Detection of an Impending Collision Carissa M. Lemon[1](clemo001@ucr.edu), George J. Andersen[1]; [1]University of California, Riverside

Previous research has shown opponent motion mechanisms in area MT average velocities across local regions in the visual field. In addition, research has shown that detecting an impending collision with an approaching object on a linear trajectory is specified by the object maintaining a constant bearing (position in the visual field). Given these findings, we examined whether velocity information adjacent to an approaching object might alter the ability to determine the bearing of the object---as a result of local motion averaging---and reduce collision detection performance. To examine this issue 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 along an arc (±20°). 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. Two independent variables were manipulated: the presence of adjacent velocities (scene objects present vs. scene objects absent) and display duration (1000ms, 3000ms, and 5000ms). We found that collision detection performance (d') decreased with the presence of scene objects ($F(1, 5)= 8.978$, $p=0.0302$). These results indicate that the ability to determine bearing information for detecting a collision is altered by the presence of adjacent velocities an effect likely due to velocity averaging of opponent motion mechanisms.

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36.449 The curvature of the background affects the perception of 3D object motion Junjun Zhang[1](junjunz@gwu.edu), Myron Braunstein[2], George Andersen[3]; [1]George Washington University, [2]University of California, Irvine, [3]University of California, Riverside

Optical contact with a flat background is important for the perception of object location in a 3D scene (Meng & Sedgwick, 2001, 2002) and for the perception of 3D object motion with cast shadows (Kersten, 1997). In the present study, we investigated the effect of background curvature on the perceived trajectory of an object moving in a 3D scene. In the first experiment, observers were presented with a sphere moving in a horizontal plane at eye level against a grid background. The trajectory of the sphere was concave, convex or straight, indicated by changes in its angular size and angular speed during the motion sequence. The background was flat or curved in the horizontal direction, with concave or convex curvature indicated by the spacing of the horizontal and vertical grid lines. Observers were asked to judge the direction of the sphere's motion (convex or concave). The results showed that the judged curvature of the object's motion depended almost entirely on the direction of curvature of the background. In the second experiment, observers were presented with two displays on each trial, differing in both the amount of curvature of the motion path and the amount of curvature of the background. Both curvatures were in the same direction (either convex or concave). The observers were asked to judge which display showed the more curved motion path. Judgments of the curvature of the sphere's motion were largely determined by the curvature of the background, with the motion path of an object judged as more curved when it was displayed against a more curved background. Our results clearly indicate that, when an object is moving against a curved background, both the perceived direction and the perceived amount of curvature of the object's trajectory depend primarily on the curvature of the background.

Acknowledgement: NIH grant EY18334

36.450 Path Is Encoded by Spiral-Selective Cells in MSTd Oliver W. Layton[1,2](owl@cns.bu.edu), N. Andrew Browning[1]; [1]Center for Computational Neuroscience & Neural Technology, [2]Program in Cognitive & Neural Systems

Neurons in primate MSTd exhibit selectivity to a continuum of spiral optic flow patterns (Graziano et al. 1994, J Neurosci), but the function of this sensitivity is unknown. MSTd is believed to encode the direction of self-motion (heading) because many neurons in MSTd respond to radially-expansive optic flow, which is experienced by an observer traveling along a straight path without body rotations. Yet, humans often travel along curvilinear paths and due to the rotation introduced by the path curvature, the optic flow patterns appear distinct from those produced by travel along straight paths. The neural mechanisms underlying the perception of path are unknown. Froehler & Duffy (2002, Science) discovered "path-selective cells" in MSTd that elicited differential activity when a monkey traveled clockwise and counterclockwise around a circle. The sequence of optic flow fields experienced by the monkey were identical in either case, but in reverse-order. Our analysis indicates that the temporally-accumulated optic flow yields distinct spiral patterns for clockwise and counterclockwise movements, for which we predict the "path-selective cells" are selective. We introduce a model that clarifies the role of primate MSTd in heading and path perception. Model neurons compete in visuotopic and pattern selectivity space, defined by a continuum spanning radial, spiral, and center optic flow. The distribution of activity peaks across MSTd cell subpopulations that are sensitive to different spiral optic flow patterns at the same spatial location corresponds to perceived path curvature judgements in human subjects. Humans produce systematic errors in their judgments of future curvilinear path depending on gaze and eye movements (Li & Cheng 2011, Journal of Vision). In conditions whereby human subjects under-(over-)estimated path curvature, MSTd subpopulations sensitive to radial (spiral) optic flow were most active. The model simultaneously represents heading and perceived path across the population activity in MSTd.

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36.451 Embodied Memory Allows Low Vision to Perform Like High Vision When Perceiving Events Jing Samantha Pan[1](jingpan@indiana.edu), Geoffrey Bingham[1]; [1]Indiana University

Introduction: In low vision, high frequency image structure is not available yielding low recognition performance. However, optic flow provides a depth map of 3D layout and motions allowing good recognition. Visual motion measurement uses low spatial frequencies available to low vision. Finally, optic flow and image structure are intrinsically related in vision because optic flow takes image to image. Pan et al (submitted) have found that optic flow information about 3D layout and progressive occlusion calibrates subsequent image structure, which then functions as embodied memory allowing identification of hidden target locations after significant delay. We now test whether this optic flow and image structure relation enables observers to recognize objects using blurry image structure that has been calibrated by optic flow. Method: Videos of eight daily events were processed with low-pass filters and thus, highly blurred. Twenty frames from each video were presented in five phases. The task was to describe each event. Phase 1: images presented one at a time. Phase 2: twenty images presented with white masks between frames (no optic flow). Phase 3: twenty images presented in sequence without masks (optic flow). Phases 4 and 5 were the same as Phase 1, except Phase 4 was immediately after Phase 3, and Phase 5 was five days later. Results: In Phases 1 and 2, the rates of correct event identification were 11% and 26%. In Phase 3, the rate increased to 88%, and dropped to 77% in Phase 4, and persisted after five days, 72% in Phase 5. With identical image structures, post-motion performance was vastly better than pre-motion performance. Conclusion: Optic flow calibrates image structures to allow accurate recognition using the blurred (nonfunctional) static images after motion ceases. Embodied memory means that low vision observers can perform better than allowed by low vision image structure alone.

Perceptual organization: Surfaces, segmentation

Sunday, May 12, 2:45 - 6:45 pm

Poster Session, Vista Ballroom

36.502 Real-world scene perception and perceptual organization: Lessons from Computer Vision Lauren Barghout[1](lauren.barghout@gmail.com), Jacob Sheynin[1,2]; [1]Eyegorithm Inc , [2]U.C. Berkeley

Purpose: Extensive research into the architecture of human scene perception and human figure-ground segmentation show that both local and configural processes play a role. Local factors include bottom-up edge segmentation enabling small regions to be fused into figural regions. Configural factors include top-down processes such as grouping and meaningfulness. Barghout (2009, 2011) suggested a natural-scene-perception architecture comprised of nested hierarchies of "spatial taxons" with the rank-frequency distribution predicted by a law of least effort, where attentional resources were minimized and utility optimized. Because computer vision models often provide insight into human perception, we decided to build a computer vision segmentation model that used spatial-taxon designation as a "meaningfulness" configural cue. Methods: The computer model used fuzzy-logic inference to simulate low-level visual processes and few rules of figure-ground perceptual organization. The model was required to conform to a spatial-taxon's "meaningfulness" cue. We collected 70 real images composed of three "generic scene types", each of which required a different combination of the perceptual organization rules built into our model. We then used our model to segment the generic scene types. Two human subjects rated image-segmentation quality on a scale from 1 to 5 (5 being the best). Results: The majority of generic-scene-type image segmentations received a score of 4 or 5 (very good, perfect). ROC plots show that this model performs better on generic-scene-type images than normalized-cut ((Martin, Fowlkes, Tal, and Malik (2001).

36.503 Beyond Fixation: Ensemble Coding and Eye Movements Benjamin Wolfe[1](bwolfe@berkeley.edu), Anna A. Kosovicheva[1], Allison Yamanashi Leib[1], David Whitney[1]; [1]University of California, Berkeley

Ensemble perception has been shown for a wide range of stimuli, including orientation, motion, and size (Watamaniuk, et al., 1992; Dakin et al., 1997; Ariely, 2001; Chong and Treisman, 2003), faces (Haberman and Whitney, 2007) and biological motion (Sweeny, Haroz and Whitney, 2012), yet little is known about the influence of ensemble coding on eye movements. In the present study, subjects were shown an array of 24 faces with similar emotional expressions (drawn from a larger set of 147 morphs spanning happy, sad and angry), either in a random arrangement or spatially organized around the mean (such that adjacent faces had similar expressions). Subject's eyes were tracked (EyeLink, 1000 Hz) during 1.5s of free viewing, following which subjects were asked to report the mean emotion of the array. We used a regression model to fit subjects' response errors on the basis of each fixated face. For the randomly arranged displays, the model explained a significant proportion of the variance in subjects' response errors; the perceived ensemble expression was well-predicted by a running average of the fixated faces. On the other hand, for the organized displays, the model accounted for a substantially smaller proportion of the variance. An additional regression model, which fitted subjects' response

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errors on the organized trials based on the fixated face that was closest to the mean, was also not significant. The results indicate that perceived ensemble expression is based on the particular faces that are fixated only when the faces are randomly arranged, not when they spatially organized.

36.504 **Multi-scale selectivity to figures in primate V4** Arash Yazdanbakhsh[1](yazdan@bu.edu), Oliver Layton[1]; [1]Center for Computational Neuroscience and Neural Technology (CompNet)

Neurons in primate V4 have been shown to respond to curved contours and local convexities/concavities (Pasupathy & Connor 1999). Evidence indicates that V4 neurons do not passively integrate contrast, but rather their response depends on figure-ground segregation. When the receptive field is centered on the edge of a figure, substantial numbers of V4 neurons elicit a selective response, depending on which side the figure is located (border-ownership) (Zhou et al. 2000). V4 neurons demonstrate response suppression when shapes to which they are selective are occluded by another (Bushnell et al. 2011), respond to shapes when they appear at a variety of sizes, and have a spectrum of receptive fields sizes that grow at peripheral eccentricities (Piñon et al. 1998). How do V4 cells achieve their selectivity to multiple shapes at different spatial scales and suppress responses outside of figures? We introduce a model of primate V4 in which neural units with a range of receptive field sizes and scatter at proximal visuotopic positions compete to suppress responses outside of figures. To account for the high degree of variance in V4 cell selectivity (Hegdé & van Essen 2006), we sample model V4 receptive field shapes from the Zernike polynomial basis, which is capable of fitting all geometrical patterns observed in V4. In the model, competitive interactions across scale and space generate activity peaks for scales and locations at which figures likely appear in the visual scene. Another layer of units groups the resultant activity from spatially-offset V4 subpopulations and elicits responses inside of figures in the visual scene. Results show that the exterior of figures tends to elicit uniform activity across units with different receptive field sizes and those units are suppressed through competition. Model results elucidate the importance of convexity and closure in figure-ground segregation.

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36.505 **Why is the tilt after-effect selective to local but not global luminance-contrast polarity?** Elena Gheorghiu[1](elena.gheorghiu@psy.kuleuven.be), Jason Bell[2], Frederick A.A. Kingdom[1]; [1]McGill Vision Research, Department of Ophthalmology, McGill University, Montreal, Canada , [2]Department of Psychology, Australian National University, Canberra, Australia

Aim: Prolonged exposure to an oriented line oppositely shifts the perceived orientation of a subsequently observed line, a phenomenon known as the tilt aftereffect (or TAE). The TAE transfers across luminance contrast polarity (Magnussen & Kurtenbach, 1979, Perception 8(5), 523-528), suggesting that either the polarities of local detectors are discarded before combining to encode the global orientation of the line, or that polarity is discarded after the global orientation of the line is encoded. Here we test between these two alternatives. Methods: The TAE was measured using line stimuli constructed from strings of 'dark' or 'white' elongated Gaussian micropatterns. Adaptors were either all white, all dark, one-alternating or two-alternating polarities. Test lines were either all white or one-alternating polarity. Results: (i) TAEs with all-white tests were small with one-alternating polarity adaptors, increased slightly for two-alternating polarity adaptors, and were largest with all-white or all-black adaptors. (ii) TAEs were also large when the test was one-alternating, irrespective of the adaptor type. Conclusion: The fact that alternating polarity adaptors produced only weak TAEs in all-white tests supports the idea that for 1st-order line orientation mechanisms polarity is discarded only after global line orientation is encoded. However the existence of strong TAEs for alternating polarity tests suggests that alternating polarities are combined by 2nd-order line orientation mechanisms. The asymmetry in the magnitude of TAE between alternating-polarity adaptors with white tests, and white adaptors with alternating-polarity tests, can be explained by an imbalance in the population of neurons sensitive to 1st- and 2nd-order stimuli, in that the 2nd-order stimuli are encoded by a subset of the mechanisms sensitive to 1st-order stimuli. The similar size TAE obtained with white adaptor/test and alternating polarity adaptor/test suggests that there are no neurons exclusively sensitive to 2nd-order stimuli.

36.506 **Representations of shape in modal and amodal completion conditions tested with shape frequency adaptation** Naoki Kogo[1](naoki.kogo@psy.kuleuven.be), Aniko Lovik[1], Vicky Froyen[2], Johan Wagemans[1]; [1]Department of Psychology, Laboratory of Experimental Psychology, University of Leuven, Belgium, [2]Department of Psychology, Center for Cognitive Science, Rutgers University

While we do not see the occluded part in amodal completion, we still have an unambiguous perception that the occluded surface continues behind the occluder. In modal completion, on the other hand, we actually see illusory contours. How does the visual system establish such a perception and distinguish modally completed and amodally completed surfaces? A higher level representation of surface shapes can influence the figure-ground and the border-ownership computations at a lower level. The shape representation at the higher level may have a different effect on modal and amodal completion. Specifically, only in modal completion, the lower level neurons may be activated corresponding to illusory contours. Conventionally, the completion phenomenon is investigated with simple shapes in which smooth interpolation is plausible. However, what if an image suggests an illusory surface with a complex shape? Can the modally completed contours reflect the higher level shape representation instead of a smooth interpolation of the inducing edges? To investigate the representation of illusory surfaces, we applied the shape frequency adaptation paradigm (Gheorghiu & Kingdom, 2007, Vision Research, 47(6), 834–844). They showed that after presenting a sine wave for a sufficient time, the perception of the frequency in a sine wave presented next is affected due to frequency adaptation. If a variation of the Kanizsa square is constructed with sine wave contours, it is possible that the sine wave illusory contours are perceived, which may cause frequency adaptation. We tested this adaptation effect in the Kanizsa square ("modal"), a variation of Kanizsa square where amodal completion is perceived ("amodal"), and occluded surfaces ("occlusion"), all accompanied with sine wave contours. We observed configuration-dependent effects: the modal figure created a stronger effect than the other figures. We report a detailed analysis of the data and discuss their implications for models of modal and amodal completion.

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36.507 **Semantic Priming Affects Figure Assignment** Andrew J. Mojica[1](ajmojica@email.arizona.edu), Mary A. Peterson[1]; [1]University of Arizona

Figure assignment entails competition between object properties on opposite sides of borders. The figure is perceived on the side of the border that wins the competition. Ample evidence indicates that configural familiarity is among the competing object properties. Here we investigate whether priming the semantics of a familiar object suggested along one side of a border increases its likelihood of winning the competition. To prime semantics we presented brief masked exposures of object names before brief masked exposures of displays where a portion of a familiar object was suggested on one side of a central border separating two equal area black and white regions. Participants reported whether the figure lay on the left or right side of the central border (side and color of the familiar configuration were balanced). Participants were unaware of the presence of the word prime. The word named either the Same Object (SO) or a Different Object (DO) as the familiar object suggested in the display. In the DO condition, the word named an object either in the Same Category (DO-SC) or a Different Category (DO-DC) as the familiar object suggested in the display, where category was defined as natural versus artificial objects. The familiar configuration was perceived as figure more often in the SC conditions (SO: 74%; DO-SC: 74%) than in the DC condition (DO-DC: 67%), $p = 0.013$. Thus, the likelihood of perceiving a familiar configuration as figure is increased by prior activation of its semantics. Together with other results supporting the hypothesis that the semantics of objects potentially present on opposite sides of borders are accessed before figure assignment is completed (Peterson, et al., 2012; Sanguinetti & Peterson, VSS 2012), these results indicate that the meaning as well as the shape of familiar configurations is weighed in figure-ground competition.

Acknowledgement: NSF BCS 0960529

36.508 **Anomalous 3D structure-from-motion arises from accretion-deletion and figure-ground cues** Vicky Froyen[1,2](vickyf@rutgers.edu), Jacob Feldman[1,2], Manish Singh[1,2]; [1]Center for Cognitive Science, Rutgers University, [2]Department of Psychology, Rutgers University

We present a novel phenomenon involving an interaction between accretion-deletion and figure-ground. Our displays consisted of alternating light and dark regions containing random-dot textures, which moved horizon-

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tally at constant speed, but in opposite directions in alternating regions. Due to the ambiguous nature of the accretion-deletion cue (accretion-deletion occurs equally on both sides of each contour), they were consistent with a percept of either the light regions being in front, with the dark regions moving amodally behind them; or vice versa. Surprisingly, the regions perceived as figural are also perceived as 3D cylinders rotating in depth---even though each region has constant velocity (hence inconsistent with 3D rotation). However, this allows the visual system to explain accretion-deletion on both sides: On one side accretion-deletion is attributed to occlusion behind another surface, on the other side it is attributed to self-occlusion due to 3D rotation. We found we could easily bias the percept towards either of the two interpretations (light or dark regions as rotating in 3D) by manipulating geometric cues to figure-ground. Our experiments used multiple geometric cues, including convexity, parallelism, symmetry and relative area. Subjects indicated which regions---light or dark---they perceived as rotating. The results showed that geometric cues biased the percept of 3D rotation in proportion to their strength (convexity>parallelism=symmetry). Moreover, the proportion by which subjects perceive a particular region as rotating decreased monotonically with its area size. On the methodological side, this phenomenon provides a novel way of measuring figure-ground perception, since the percept of 3D rotation nicely tracks the strength of the figure-ground cue. On the theoretical side, our results highlight the need for studying geometric figure-ground cues and depth-from-motion cues as an ensemble. The observed interactions between accretion-deletion and geometric figure-ground cues cannot be explained by standard accounts of accretion-deletion or structure-from-motion.

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36.509 **Infants (5.5 months old) use shape regularity to segment objects from their backgrounds**

Elizabeth Salvagio[1](bsalvag@email.arizona.edu), Rebecca L. Gomez[1], Mary A. Peterson[1]; [1]University of Arizona

Infants are confronted with a visual world containing a wealth of colors, textures and patterns. How do infants segment objects from backgrounds in static displays? Brady and Kersten (2003) showed that adults could recognize a novel object they had viewed repeatedly against changing 3D backgrounds, suggesting shape regularity enabled segmentation. Here we use a habituation paradigm to investigate whether shape regularity alone enables segmentation in 5.5 month-old infants. Unlike previous studies of infant's segmentation abilities that used moving displays, we used static displays. The novel objects viewed by infants were 3D objects modeled after Brady and Kersten's digital embryos; they were simplified to accommodate infants developing vision. A priori preferences for the novel objects were determined in a pretest where infants viewed them on a white background. During a habituation phase, infants viewed one of the novel objects presented on eight 2D plaid backgrounds, repeated up to three times. On each trial the habituation object was accompanied by a labeling phrase ("Look at the toma(modi). Do you see the toma(modi)?"). At post-test, infants viewed the habituation object and the other object side by side on a white background while hearing the habituation object's paired phrase. Infants looked longer at the habituation object compared to the other object at post-test, $p < 0.05$, indicating they had segmented it correctly associated its phrase during habituation. Furthermore, a pre-post-test comparison showed that infants' object preferences were modulated by the habituation trials, $p < 0.03$. This novel finding indicates that in 5.5 month-old infants shape regularity alone enables object segmentation in static displays, adding substantially to the evidence regarding how infants segment visual scenes. A second study is underway examining whether these results can be replicated with 3D backgrounds.

Acknowledgement: NSF BCS 0960529

36.510 **Surprising Evidence of Competition in a Classic Figure-Ground Stimulus Supports a Role for Background Priors in Figure Assignment**

Mary A Peterson[1](mapeters@u.arizona.edu), Elizabeth Salvagio[1]; [1]Psychology Department and Cognitive Science Program, School of Mind, Brain, and Behavior, University of Arizona

Figure-ground organization entails competition between objects that might be perceived on opposite sides of borders. Some displays don't seem to involve competition because agreement regarding the final percept is nearly unanimous. For instance, ~90% of observers report perceiving convex regions as figures in the eight-region black-and-white displays with alternating convex/concave regions that the Gestaltists used to demonstrate that convexity is a figure prior. Recently, Peterson and Salvagio (2008) showed that p(convex=figures) is high in unmasked 8-region displays exposed for 100 ms, provided that the concave regions are homogeneously colored. To model these results, Goldreich and Peterson (2012) assumed that perceiving convex regions as figures entails interpreting the concave regions as portions of a background surface, which occurs when they are homogeneously colored, on the prior that single surfaces tend to be a single color. Their model makes the surprising prediction that a background surface interpretation is considered for homogeneously-colored convex regions as well, and hence, that foreground and background interpretations for homogeneous convex regions compete before figure assignment occurs. Because competition takes time, evidence that it takes longer to perceive convex regions as figures in displays with homogeneous rather than heterogeneous convex regions would support the hypothesized competition. We tested this prediction by masking 100-ms displays immediately or 50-ms later. P(convex=figure) was larger for displays with heterogeneously- than homogeneously-colored convex regions in both display-mask SOA conditions, $p<.01$. With a display-mask SOA of 150 ms, p(convex=figure) for heterogeneous convex displays was 85%, whereas p(convex=figure) for homogeneous convex displays did not reach 85% even with display-mask SOAs of 300 ms. Investigating the time course of figure assignment supports a model positing a role for background priors as well as figure priors and reveals that a classic demonstration of the convex figures prior is surprisingly ambiguous.

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36.511 **Convexity as a Cue to Figure-Ground Segmentation in Children**

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Adults are more likely to perceive as figures regions that are bound by convex rather than concave contours, a likelihood that increases with the number of regions displayed, revealing an effect of context (Peterson & Salvagio, 2008). To test the development of this convexity bias and the effect of context, we examined the strength of convexity as a figural cue in 5-year-olds and adults (n=24/age). Participants were shown computer displays composed of alternating convex and concave regions that differed in luminance (black or white). Displays consisted of two or eight regions. The task on each trial was to identify the colour of the figure. Both 5-year-olds and adults identified the convex regions more often as a figure for displays containing eight alternating regions than for displays containing only two regions ($p <.01$), suggesting an effect of context. No difference was observed between age groups ($p > .10$). To further explore the development of these effects throughout early childhood and to verify that our previous results were reliable, we conducted a follow-up study examining the strength of convexity in 3-year-olds, 5-year-olds, and adults (n=12/age). Instead of a computer monitor, stimuli were presented on laminated cards to make the task more appropriate for the 3-year-olds. Displays comprised four or eight regions. All age groups identified the convex regions as a figure more often for displays containing eight regions (90%) compared to displays containing only four regions (81%, $p <.01$). There was no significant difference in the proportion of trials on which the convex regions were identified as the figure across the three ages ($p > .10$). Under the current testing conditions, the strength of convexity as a figural cue when performing figure-ground judgments and the effect of context on these judgments appear to be adult-like by 3 years of age.

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36.512 **The effects of aging on figure/ground perception: Reduced competition resolution in older observers.**

Jordan W. Lass[1](jwlass@gmail.com), Patrick J. Bennett[1], Mary A. Peterson[2], Allison B. Sekuler[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University, [2]Department of Psychology and Cognitive Science Program, University of Arizona

The bias for young observers to perceive convex regions as figure increases as the number of alternating black and white (BW) convex and concave regions increases from 2 to 8 (Peterson & Salvagio, 2008). Lass et al. (VSS 2012) replicated this convexity context effect (CCE) in younger observers for BW stimuli, but found significantly reduced CCEs in older observers. Based on previous research (Salvagio & Peterson, VSS 2011, 2012), we hypothesized that older observers might have difficulty resolving the competition between figure and ground interpretations for homogeneously coloured convex regions in 8-region BW displays. Salvagio and Peterson reduced competition for convex regions by alternating heterogeneously coloured convex regions with homogenously coloured concave regions. For their younger observers, CCEs emerged earlier in time. We examined whether the convexity bias in older observers is influenced by the colour heterogeneity of convex and concave regions. Older (n = 15) and younger (n =

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16) observers viewed four types of 8-region displays blocked by region-type: (1) both-homogeneous (BW), (2) homogeneous-concave/heterogeneous-convex, (3) heterogeneous-concave/homogenous-convex, and (4) both-heterogeneous. On each trial, observers fixated a central border and reported whether a red probe presented to the left or right of center was on or off the region perceived as figure. Probe location was balanced, and the dependent variable was the proportion of trials the convex region was perceived as figure. Convexity biases were larger for displays with homogeneous- versus heterogeneous-concave regions, p <.001; this difference did not differ between age groups. However, the difference between convexity bias measured in the homogeneous-concave and homogeneous-both (BW) conditions was greater in older observers, p <.05. This increase in convexity bias observed in older observers, specifically in displays with reduced competition, indicates that there are age differences in competition resolution ability that affect CCEs, and thus figure assignment more generally.

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36.513 **Geometric figure-ground cues override standard depth from accretion-deletion**

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Froyen et al. (ECVP2012) presented a new phenomenon involving interactions between accretion-deletion and figure-ground geometric cues. These displays contained alternating light and dark regions with random-dot textures moving horizontally at constant speed, but in opposite directions in alternating regions. When geometric figure-ground cues (convexity or symmetry) were introduced on one set of regions, subjects perceived those regions as volumes rotating in front, whereas the other regions were perceived as translating amodally behind them. This demonstrated that accreting/deleting regions, which are usually assumed to be mandatorily perceived behind, can also be perceived as self-occluding due to rotation in 3D---at least when accretion-deletion occurs on both sides of a contour. In the current project, we asked: Can geometric figure-ground cues override the standard "depth from accretion-deletion" interpretation even when accretion-deletion takes place only on one side of a contour? We used two tasks: a relative depth task (front/back), and a motion classification task (translation/rotation). In the first experiment, only one set of alternating regions contained moving texture; the other set was static. In such displays the standard accretion-deletion account would unambiguously assign farther depth to the moving regions. However, when the moving regions were convex or symmetric, they tended to be perceived as figural, and rotating in 3D (with convexity>symmetry). In the second experiment, the traditional accretion-deletion interpretation was weakened further by giving different motion directions of to the moving regions (hence weakening motion-based grouping). Our results show that the standard "depth from accretion-deletion" interpretation is easily overridden by geometric cues to figure-ground, as well as motion-based grouping across non-adjacent regions. When this happens, the accreting-deleting surface is perceived as self-occluding, hence, as rotating. Overall, the results demonstrate a rich interaction between accretion-deletion, figure-ground, and structure-from-motion that is not captured by existing models of depth from motion.

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36.514 **Kanizsa shape discrimination and contour integration deficits in schizophrenia: What is the role of spatial frequency?**

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Introduction. Patients with schizophrenia exhibit a reduced ability to distinguish Kanizsa shapes and integrate collinear elements (gabors). Patients also poorly process low spatial frequencies (SFs), which reflects dysfunction along the magnocellular pathway. Here, we ask: Will patients' perceptual organization deficits disappear when low SFs are removed from the stimuli? Method. To address this question, we tested 11 patients and 9 healthy controls on two classic paradigms. In the contour integration task, subjects identified the screen quadrant in which a closed chain of co-circular gabors appeared. Task difficulty depended on the number of noise gabors co-presented with the target, and the stimulus was scaled to produce two SF conditions (4 and 12 cycles/deg). In the discrimination task, subjects determined on each trial whether four pac-men formed a fat or thin Kanizsa shape (illusory condition) or whether four downward-pointing pac-men were rotated left or right (fragmented condition). The pac-men were presented with all SFs (broadband) or with low SFs removed. Task difficulty depended on the amount by which the pac-men were individually rotated, and illusory shape discrimination was measured as the performance difference between the illusory and fragmented conditions. Results. Patients are at least marginally worse at contour integration and illusory shape discrimination, and such differences do not depend on SF structure. Moreover, contour integration and illusory shape discrimination are strongly correlated for both groups, suggesting a common underlying mechanism. Conclusions. The ability to distinguish Kanizsa shapes and detect gabor chains is reduced in schizophrenia, perhaps as a result of a disturbance to a common underlying mechanism. Crucially, illusory shape discrimination and contour integration deficits in SZ cannot be explained in terms of poor low SF processing, and therefore probably cannot be explained in terms of magnocellular dysfunction.

36.515 **Temporal facilitation in the integration of contours**

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Motion can be a rich source of information for the contour completion of objects that are partially occluded. In the particular case of spatiotemporal boundary formation (SBF), motion is critical for the perception of contours. This means that the system integrates the image fragments that appear along the movement over time. This process would require, in addition to the mechanisms of spatial contour integration, a process capable to accumulate the information over time. Such process could be instantiated neurally by a temporal facilitation mechanism. In this study, we investigate the plausibility of such a mechanism by mean of a psychophysical study. Using a masking/facilitation paradigm, we studied the interaction between two stimuli (mask and target) of the same orientation, located adjacent one respect to the other (0 deg), and with angles of 45 and 90 deg between them, as a function of the delay between the presentation of the target respect to the mask. An angle of 90 deg between the patches corresponds to collinearity. The stimuli were Gabor patches with a spatial frequency of 6 c/deg. The separation between patches was 3 wavelenghts. Three observers participated in the experiment. We used a 2AFC method to measure the threshold elevation of the target in presence of the mask, respect to the threshold obtained without mask. Results show that for 0 and 45 deg, the time course of facilitation, defined as a negative threshold elevation, has peaks around 25 ms for 0 deg, and 35 ms for 45 deg. For 90 deg, the maximum facilitation occurs when mask and target are presented simultaneously and decreases with increasing delay. The peaks of facilitation found for 0 and 45 deg resembles a spatiotamporal correlator that may account for a mechanism that integrates temporally signals that occur along the object motion path.

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36.516 **A neuro-computational model for the perception of contours defined by motion**

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In real life, the human visual system continuously faces the difficulty of obtaining information about objects of interest from the visual scene. Such information is often incomplete or spatial and/or temporally fragmented. It has been shown that the visual system is highly efficient in performing the contour completion. Such filling-in of missing contours occur in static and dynamic situations, but there are cases in which motion becomes critical for this task. A class of phenomenon of particular importance in this context is the contours perception due to the accretion and deletion of texture due to the relative motion between two surfaces (Spatiotemporal Boundary Formation; SBF). Here, we present a neuro-computational model that extracts the contours of a moving figure from the the accretion and deletion of its texture elements. The model consists of three modules: an early stage that mimics the receptive fields of circular on-off LGN cells, and the receptive fields of oriented cells of the primary visual cortex. A second stage that implements the lateral connections among cells, which provide spatial facilitations and inhibitions, constrained by the law of the association fields. A third module that implements temporal facilitations among cells, that work as spatiotemporal correlators. These facilitations are modulated by motion signals such that they are maximal in the direction of motion. We performed model simulations by using sequences of artificial images. The model performance was estimated by calculating the error in the estimate of the contours, respect to the ground truth given by the stimuli. Simulations were performed by varying speed, dot density and shape. Results show that the

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model can account for most results on SBF found in the literature. We also used anorthoscopic, in addition to SBF stimuli, and found that the model performs acceptably well reconstructing the object shape in this condition.

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36.517 **Integration of Contour Shape Information** Patrick Garrigan[1](p-garriga@sju.edu), Christina Hamilton[1]; [1]Department of Psychology, Saint Joseph's University

Visual working memory capacity for shapes is dependent on the complexity of the shapes stored (Alvarez & Cavanagh, 2004). Consequently, it is important for the visual system to discover regularities and exploit them to form more efficient representations of complex shapes. Some regularities, like symmetry, are perceived efficiently, but the detection and encoding of other regularities may require extended viewing if the shapes are sufficiently complex (Baylis & Driver, 2001). Together, these results suggest that, during initial viewing of novel shapes, the visual system may be discovering regularities and building representations that utilize these regularities. Here we investigate the formation of visual working memory representations of novel shapes. We show that the formation of 2D contour shape memory traces can occur over relatively long time scales (several seconds) and involve integration of shape information across multiple views. Using a novel change detection paradigm in which subjects try to determine if a flickering movie of a single 2D contour shape is slowly changing, we show that large cumulative changes often go undetected. Our results demonstrate that this effect is not due to insufficient visual memory capacity or durability. Rather, it appears to be the consequence of automatic updating of the shape representation. To support this hypothesis, we show that, even when subjects are explicitly instructed to encode the initial shape of a morph sequence, viewing the sequence causes the memory of that initial shape to be biased towards the final shape in the sequence.

36.518 **Peripheral contour integration favors convex contours** Bart Machilsen[1](bart.machilsen@ppw.kuleuven.be), Maarten Demeyer[1], Johan Wagemans[1]; [1]Laboratory of Experimental Psychology, University of Leuven

Integrating local edges into spatially extended contours is a fundamental step in perceptual organization. This process of contour integration is known to depend on the local alignment and relative spacing of adjacent contour elements. To investigate how the global curvature polarity of a contour influences contour integration in the visual periphery, we embedded circular arc contours in Gabor displays. The contours could appear at three different eccentricities and were either convex or concave with respect to the central fixation position. Participants were instructed to indicate whether the contour appeared in the right or in the left half of the display. At all three eccentricities participants were faster at detecting the convex contours compared to the concave contours. We offer a possible explanation of this convexity bias in terms of natural input statistics.

36.519 **Contour integration and perceptual fading** Lars Strother[1,2](l-stroth@uwo.ca), Danila Alferov[1], Tutis Vilis[1,2]; [1]Brain and Mind Institute, University of Western Ontario, [2]Department of Physiology and Pharmacology, University of Western Ontario

The 'association field' (Field et al. 1993) model of contour integration predicts that contours comprised of sufficiently proximal edge elements become increasingly detectable with decreasing inter-element misalignment. We investigated a possible relationship between the association field and the perceptual fading of a contour under conditions of impending camouflage. We measured the effect of inter-element alignment on the duration of continued contour visibility using contours that were visible upon onset but faded into a camouflaging background within a few seconds. Even though the elements comprising the contours remained superimposed on the background, the contours always became fully camouflaged within a few seconds after contour onset. Our method allowed us to study the effects of inter-element orientation for considerably greater inter-element distances than those used in detection experiments. We used a continuous range of angular deviations from collinearity. This resulted in a parametric effect of inter-element alignment on the duration of perceptual fading such that contours comprised of maximally co-aligned elements remained visible (~500 ms) longer than those comprised of more randomly oriented elements. Consistent with findings from contour detection studies, contours remained visible longest (> 3 s) when co-aligned elements were parallel to the global contour ('snakes') as compared to perpendicular ('ladders'). We conclude that the effect of inter-element alignment on delayed contour fading reflects the sustained operation of an association field mechanism. This mechanism binds discrete visual elements into global contours as a function of synchronous onset, inter-element distance and element co-alignment.

36.520 **Detecting shapes in noise: the role of contour-based and region-based representations** John Wilder[1,2](jdwilder@ruccs.rutgers.edu), Manish Singh[1,2], Jacob Feldman[1,2]; [1]Department of Psychology, Rutgers University, [2]Rutgers University Center for Cognitive Science

We investigated the detection of shapes (closed contours) in noise as a function of their complexity. As in previous work (VSS2012), we quantified complexity in several ways reflecting alternate shape-generating models. In a contour-based model, complexity is defined as the integrated surprisal along the contour, that is, the summed negative log probability of the sequence of turning angles defining it. Alternatively, in a skeleton-based model of shape, complexity is defined as the surprisal of the shape given its generating skeleton, that is, the negative log probability of the shape's boundary conditioned on an estimated skeleton. The two models have the same basic probabilistic conception but differ in assumed generating model. In VSS2012 we applied these measures to natural shapes (animals and leaves), but these shapes necessarily result in an irregular and sparse sampling of the shape space. Here we present a series of more controlled experiments in which we manipulated the structure of the target shape in order to distinguish the potentially separate effects of contour complexity and different components of skeleton-based shape complexity, such as the log prior and log likelihood. Subjects detected closed contours embedded in background noise (2IFC task). We parametrically varied several shape factors, including the number of parts in the shape, and the variability of the contour around its internal skeleton (hence the amplitude of contour noise). The number of parts influences the prior probability of the skeleton, while the variability influences the complexity under the contour model as well as the likelihood under the skeletal model. Both factors show significant influences on shape detectability, providing evidence for both contour-based and region-based representational formats. The results shed light on basic processes of perceptual organization, including object segmentation (extracting whole shapes from cluttered scenes) and shape representation.

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Development: Typical development across the lifespan

Sunday, May 12, 2:45 - 6:45 pm

Poster Session, Vista Ballroom

36.522 **Differentiation of Impossible and Possible Figures Through the Exploration of Ocular Movements in Young Children.** Vanessa Adamson[1](adams944@umn.edu), Sherryse Corrow[1], Sarah Shuwairi[2], Jordan Mathison [1], Albert Yonas[1]; [1]University of Minnesota-Twin Cities , [2]Lehman College

It is clear that adults can use pictorial depth cues to detect that a simple drawing specifies an impossible object. Recent studies have suggested that 4-month-old infants have a similar ability. Infants looked at a drawing of an impossible object for a longer period of time than a drawing of a possible object (Shuwairi and Johnson 2012). The findings suggest that sensitivity to depth order specified by the location of T-junctures as well as the ability to integrate local depth information into a global representation is present early in development. In addiction, work by Young and Deregowski (1981) has found that 7-year-old children were less able to discriminate possible objects compared to older children. The goal of this work is to use an eye tracking apparatus to investigate developmental changes in the sequence of fixations that take place when impossible objects are viewed. As part of this project fixation durations were recorded using a Tobii eye-tracker on 8-year-old-children. We found that 10 out of the 12 children ($p<0.05$ by sign test) fixated the relevant part of the impossible figure longer than the corresponding possible region. Future work will investigate developmental changes in the ability children to detect the impossible of a variety of drawings and the sequence of eye fixations used in the task.

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36.523 **The role of heterophoria and its adaptation in typically developing children** Erin Babinsky[1](ebabinsk@indiana.edu), Vidhyapriya Sreenivasan[2], T. Rowan Candy[3]; [1]School of Optometry, Indiana University

Visual experience during postnatal development is dependent on the accommodative and vergence systems, in controlling retinal image quality and correspondence. How young children's oculomotor systems coordinate these responses in the presence of hyperopic refractive error and a narrow interpupillary distance is poorly understood, and is central in understanding refractive strabismus. One key problem is how the systems compensate for additional convergence driven by coupled accommodation overcoming their hyperopia. Methods: Eye alignment was recorded using Purkinje image eye tracking at 25Hz, while subjects viewed naturalistic targets monocularly for one minute and then binocularly for 5s, at 33cms. The dissociated heterophoria was derived from these data as a representation of resting alignment of the eyes. The protocol was then repeated to test adaptation with the binocular phase lengthened to 60s with 10 prism diopters (pd) of base out prism (increasing the vergence demand). Subjects were typically-developing children aged 2-10 years (n = 49) and adults (n = 16), who also underwent a clinical eye examination. Results: While the presence of uncorrected hyperopia (mean +0.92D, SD 1.1D) in the children suggests they should have a convergent eye alignment in dissociated conditions, 73% had a divergent eye alignment (exophoria <-2pd) for the 33cm viewing distance, as compared to 81% in adults. The mean heterophoria was -4.0pd (SD 4.6) in children and -7.1pd (SD 5.3) in adults (p = .02). At the end of the adaptation period, the children's mean heterophoria was 2.2pd (p = .002) more convergent than their baseline phoria and took 40s to return to baseline value. Despite the presence of hyperopia, these young children typically are exophoric for this near viewing distance. Their apparent ability to adapt suggests that this misalignment may be desirable.

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36.524 **Signal Clarity for Infant Numerical Representation**

Lisa Cantrell[1](cantrell@indiana.edu), Ty Boyer[2], Linda Smith[1]; [1]Indiana University, [2]Georgia Southern University

Previous research has established that young infants represent and discriminate large numerosities approximately and do so in ways that appear limited by the ratio differences between quantities (e.g., Cordes & Brannon, 2009a; Xu & Spelke, 2000). That is, infants at 6 and 9 months have shown successful discrimination of numerosities that differ by a 2:3 ratio (Cordes & Brannon, 2009; Xu & Arriaga, 2007) but have failed in smaller ratio comparisons (e.g., 3:4 and 4:5, Feigenson, Carey, & Hauser, 2002; Xu & Arriaga, 2007). We hypothesize, however, that successful discrimination depends on the clarity of the signal presented to the infant. We suggest that signal clarity is a function of 1) the statistical regularities that come from the presentation of redundant and correlated stimulus information, as well as 2) certain visual properties, such as density of items that make numerical information easier or more difficult to extract. In Study 1 we tested 20 nine-month-old infants in a 3:4 ratio comparison in which they were presented redundant correlated information across the habituation trials. Whereas previous studies indicated failure when dimensions were not redundant, looking time measures in our study comparing the last habituation trial to the first novel trial indicated successful discrimination, t(19)=2.56, p=.019. In Study 2 we tested 66 six-month olds in a 2 v 3 visual comparison—a comparison in which infants have previously succeeded (e.g., Antell & Keating, 1983; Starkey & Cooper, 1980). In this study infants successfully discriminated the sets when items were spaced far apart at a low density (looking time to novel versus familiar, t(31)=2.81, p<.01); however, infants failed when items were closely spaced at a high density, t(33)=1.60, p=.14. The results suggest that both redundancy of visual information as well as item density contribute to signal clarity and influence representation and discrimination of numerical stimuli.

36.525 **Exploring the visual sensitivity for topological property in 0-4 day-old** newborn infants

Sarina Hui-Lin Chien[1](sarinachien@mail.cmu.edu.tw), Yun-Lan Lin[1,2], Wan-Ting Yeh[1,2], Yun Lin[1,2], Hsin-Yueh Hsu[1], Bai-Horng Su[3]; [1]Graduate Institute of Neural & Cognitive Sciences, China Medical University, [2]Department of Chinese Medicine, China Medical University, [3]Department of Neonatology, China Medical University Children's Hospital

Introduction: Lines of evidence from adult psychophysics, brain imaging, and honeybee's behavior have supported the topology theory of visual perception (Chen, 1982). Previously, we tested young infants and found an early sensitivity for topological property around 6 weeks onward. To further explore whether such sensitivity might be innate, here we investigated infants' discriminability for topological vs. geometrical properties within 4 days after birth. Methods: The familiarization/visual paired comparison procedures were used. 46 newborns (mean age = 2.1 days) were randomly assigned to one of the three between-subject conditions: a disk vs. a ring (topologically different but geometrically similar), a ring vs. an S-shape (topologically different, total area equated), or a disk vs. a triangle (geometrically different but topologically equivalent). The stimuli were white papers (~20° visual angle) mounted on black cardboard (41cm × 26.5cm). Each trial contained a 30-sec familiarization and a 30-sec test. Infant's looking was recorded throughout, and novelty preferences were scored trial by trial. Results: Results (final N=40) showed that in the disk vs. ring condition, neonates (n=14) showed a significant novelty preference for the ring (.57, p=.021) when familiarized with the disk. When familiarized with the ring, they showed a negative preference for the disk (.42, p=.077). In the ring vs. S-shape condition (n=12), infants showed a significant novelty preference for the ring (.58, p=.022) when familiarized with the S-shape. When familiarized with the ring, a slight non-significant preference for the S-shape was found (.54, p=.125). In the disk vs. triangle condition (n=14), no significant preferences were observed in either directions. In sum, an intrinsic preference for the ring might have biased the novelty response; nevertheless, the overall results suggests that the ability to process topological properties seems to be present at birth, at least for the detection of stimuli with or without a hole.

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36.526 **The relationship between postural stability, head movements and visuomotor performance in children aged 3-11 years**

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Introduction: Manual dexterity requires that the head and body are stable so that vision can be used to generate movement and correct errors. Manual dexterity and postural control improve with age so the development of manual skill must involve changes in the relationship between head, body and hand. Nevertheless, this relationship has not been well investigated whilst participants undertake a manual task, probably because of the technical difficulties in simultaneous recording. Methods: We created a system capable of presenting visuomotor tasks whilst objectively measuring manual skill, head movements and postural sway. We explored performance in four conditions: (i) Stationary fixation; (ii) Eyes closed; (iii) Visual tracking of moving targets at slow, medium and fast speeds; (iv) Tracking the moving targets with a handheld stylus. 514 children were recruited aged 3-11 years. The strengths and difficulties questionnaire provided an index of autistic traits and these data were combined with a range of educational measures. Results: A relationship was found between postural sway with stationary fixation and manual dexterity performance. Adults were able to visually track the moving target with minimal head movements and postural sway. The younger children showed large head movements with associated postural adjustments. A clear trend towards adult behaviour was observed as a function of age. These effects were magnified when children tracked the moving target with the handheld stylus. A composite 'ASD trait' score was found to significantly correlate with manual dexterity, postural stability, and head movement. Conclusions: These results suggest our system has potential as a population level tool for objectively measuring posture and detecting developmental disorders. These results will be discussed with regard to ongoing data collection in a cohort of 13,500 children (Born in Bradford) where performance on our task can be related to genetic, health and educational data on the children and parents.

36.527 **Modulations of visual scanning of face by olfactory context in young infants**

Ornella Godard[1](ornella.godard@gmail.com), Jean-Yves Baudouin[2], Nicolas Dollion[3], Sylviane Martin[4], Karine Durand[5], Benoist Schaal[6]; [1]CSGA, UMR6265 CNRS, [2]CSGA, UMR6265 CNRS, [3]CSGA, UMR6265 CNRS, [4]CSGA, UMR6265 CNRS, [5]CSGA, UMR6265 CNRS, [6]CSGA, UMR6265 CNRS

The purpose of the present study was to evaluate whether, how, and when the visual scanning of faces is modulated through odor-induced emotional states. In other words, does an olfactory context generate specific expectations and modulate visual scanning toward adult faces in infants. 7-month-old infants (N=60) were tested. They were presented with an odorant and with a face displayed on the monitor of the eye-movement tracking system (SMI system). The odorants were selected to be pleasant, unpleasant or neutral for adults. The infants were first familiarized to a neutral face displayed 6 times following an infant-controlled procedure (i.e., the face will stay on the monitor until the infant stops looking at it). After the familiarization trials, they were exposed 4 times, again with an infant-controlled procedure, with either (i) the same neutral face with a neutral air-flow delivered in front of the nose, (ii) the same neutral face with a air-flow carrying a negative odorant (butyric acid), or (iii) the same neutral face with an air-flow carrying a positive odorant (strawberry). We hypothesized that, when displayed with an odorant, (i) infants would look longer to the adult face, and, (ii) the infants' visual scanning behavior on the neutral face should be biased to fixate facial areas involved in a specific expression. Both these hypotheses were confirmed, with an increased looking time to the face in the odor condition, mostly on the eye and nose areas. Preliminary results in 3-month-old infants will be, also, presented.

36.528 A Developmental Functional MRI Study of the Approximate Number System: Age and Math Achievement Associations to Parietal Lobe Activity Jarnet Han[1](jarnet@ucsd.edu), Elizabeth Toomarian[1], Maha Adamo[1], Frank Haist[1,2]; [1]UC San Diego Center for Human Development, [2]UC San Diego Psychiatry Department

Humans and other species are able to understand and accurately compare quantities from a very early age. This "number sense" is hypothesized to depend on an "Approximate Number System" (ANS) linked to activity in intraparietal sulcus. Recent findings suggest that the ANS possibly does not mature until adolescence, with ANS accuracy predictive of math academic achievement. However, the neural development of the ANS is not well understood. Here, we present findings from a developmental event-related FMRI study using a variant of the Panamath numerosity task (http://panamath.org) testing 46 children (6-12 years), teens (13-16 years), and adults (18-34 years). Participants were shown collections of blue and yellow dots on the left and right sides of the screen, respectively, and had to indicate which side had the greater number of dots via a button response. Task difficulty was manipulated by using four different ranges of blue:yellow dot ratios, or bins (lowest ratios more difficult). We also collected IQ, math achievement, and verbal achievement scores. All groups were less accurate at numerosity judgments in the two most difficult bins and achieved near perfect performance on the easiest two bins. Overall, children were less accurate and responded more slowly than teens and adults, and teens performed similarly to adults. We evaluated age and math achievement correlations to whole-brain FMRI BOLD activity in the hardest bin using linear regression. Age was positively correlated to increased activation in the supramarginal and angular gyrus, particularly in the left hemisphere. The Woodcock Johnson III Math Fluency test was positively correlated with activity in the right supramarginal and angular gyrus after accounting for age. These findings provide important new information about the neural development of the ANS and suggest that math achievement and age may be associated with activity in different hemispheres of the parietal lobe.

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36.529 Differential Oculomotor Activity in Young Infants Viewing Pictures of Possible and Impossible Objects Sarah Shuwairi[1](sms425@nyu.edu), Scott Johnson[2]; [1]New York University, Department of Psychology, [2]UCLA, Department of Psychology

We previously demonstrated that 4-month-old infants responded with increased looking and oculomotor activity toward pictures of impossible cubes relative to possible ones, and they fixated specifically within the critical region of impossible cubes ($p<.01$) where the anomalous junction occurred, an effect that was not observed reliably in younger infants. This suggested that 4-month-olds selectively respond to local vertices (T-, Y-junctions) diagnostic of global coherence. However, it left open the question of whether 4-month-olds would systematically respond with increased visual interest to other novel impossible figures varying in type of geometric contours (curvilinear vs. straight-edges). We recorded eye movements from 4-month-old infants as they viewed images of possible and impossible objects. We hypothesized that infants would engage in active comparison of the objects, and that impossible figures would evoke increased scanning to ascertain global structural integrity. Infants looked longer ($p<.03$) and directed a greater number of fixations ($p<.05$) on impossible relative to possible cubes. Preference scores indicated infants' partiality for the impossible cube differed from chance ($p<.05$). The effect of increased visual interest toward impossible figures generalized to other straight-edged stimuli, but not curvilinear ones. Furthermore, across all object pairs, infants initiated a greater number of fixations and looked an average of 300 ms longer in the lower halves of impossible figures relative to their possible mates ($p<.05$), whereas there were no reliable differences in fixation behavior in the top halves. The high degree of variability in infants' fixation behaviors may be due to individual differences in selective looking or emerging sensitivity to pictorial depth, or may be a stimulus-dependent response that manifests exclusively with specific shapes (impossible cubes with salient manipulations of T- and Y-junctions). Our findings suggest that several mechanisms for selectively analyzing local depth relations and ascertaining information about global 3D shape develop rapidly in early infancy.

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36.530 Visual statistics of infants' ordered experiences Swapnaa Jayaraman[1](swapnaa@indiana.edu), Caitlin M. Fausey[1], Linda B. Smith[1]; [1]Psychological and Brain Sciences Department, Indiana University

Human infants are motorically altricial. In the first few months, they basically watch their world from caregiver-determined positions before they can physically engage with their environment by holding and moving objects and themselves. Their experiences are ordered by the development of their sensorimotor systems; their motor abilities being influenced by joint forces of perceiving their environment and acting upon it [1-2]. In this paper, we describe the changing natural statistics of infant visual environments across development. We focus on 1-3 month infants who could not sit independently or hold objects, and 7-9 month old infants who could crawl and manipulate objects. A light-weight head-mounted camera was used to record the views of six younger (3 females, 3 males, average age 1.7 months) and five older infants (2 females, 3 males, average age 8 months) in their natural environment at home. Still images from 44 hours of videos sampled every five seconds were examined for the presence of faces, body parts, objects, and other background features. Results showed that faces, particularly isolated faces (without objects) dominated the views of younger infants, in addition to a lot of ceiling and wall views. In contrast, bare hands, isolated objects within close reach, and floors were prevalent in the view of older infants. The differences in occurrences of the above elements between the infants groups were significant ($p<0.001$). All theories of visual development recognize that the input matters; and there is much interest in the statistics of those experiences. Our results support the idea that infant visual experiences are ordered by motor development.

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36.531 Evidence for a general convexity assumption in 6-month-old infants. Jordan Mathison[1](mathi266@umn.edu), Sherryse Corrow[1], Vanessa Adamson[1], Carl Granrud[2], Al Yonas[1]; [1]University of Minnesota, Institute of Child Development, [2]University of Northern Colorado, School of Psychological Sciences

Intro: At previous VSS meetings, we reported that: When 6-month-old infants were presented with the concave face illusion display, lit from below, they reach more often to the apparently closest center of mask when viewing it monocularly and to the actually closer edges of the mask when viewing it binocularly. This indicates that they perceive the concave mask as convex in the monocular viewing condition. In a second study the mask was inverted and lit from the side to reduce its face-like appearance. Infants reached more often to the center of mask in the monocular condition to the same degree as in the first study. This suggests that reducing the face-like appearance of the display may not influence the infant's perception of the mask as strongly as it does with adults, who perceive a stronger illusion when the face is presented upright than when it is inverted (Papathomas & Bono, 2004). The current study aimed to investigate whether infants' use of a general convexity assumption by presenting the infants with a concave object that is unfamiliar to the infant. Method: Using a within-subjects design, we presented 6-month-old infants ($n=22$) with an unfamiliar concave object and observed the trajectory of their reaches in the binocular and monocular viewing conditions. Results: Infants reached more often to the center of the concave object in the monocular condition (61%) than in the binocular condition (32%). A paired sample t-test revealed a significant difference between the means ($t=-3.05$, $P<.01$), with a large effect size, Cohen's $d= .9159$. Discussion: These results suggest that the infants employ a general convexity assumption and perceive the concave object as convex when binocular information for depth is not available. When binocular cues specify the actual 3-D layout of the display they perceive it as convex.

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36.532 Investigating infants' inhibitory control and fixation durations in complex naturalistic and non-naturalistic scenes Irati Rodriguez Saez de Urabain[1](iurabain@gmail.com), Mark H. Johnson[1], Tim J. Smith[1]; [1]Centre for Brain and Cognitive Development. Birkbeck, University of London.

Fixation durations in infancy research are considered to be indicative of attention and information processing. Previous studies showed how fixation durations can be affected by (a) individual differences between short lookers and long lookers, (b) stimulus characteristics (e.g., static vs. dynamic), and (c) developmental changes in saccadic inhibitory control. However, the interaction between individual differences in saccade timing and top-down modulation of fixation durations by scene semantics is not known. In this study a group of infants aged 6 months were presented with (1) a set of customized naturalistic videos whereby three people perform several baby-friendly actions, (2) a second set of abstract non-social videos created from the first set, and (3) static complex images while fixation location and durations were measured. Further, all the infants performed a gap-overlap task in order to measure inhibitory control. Results from this study revealed stable individual differences in fixations durations as well as systematic changes across viewing conditions.

Sunday PM

Interestingly, fixation durations during the naturalistic videos were significantly shorter than in the abstract non-social videos, suggesting an adaptation of their looking behavior to the semantic content of the stimuli. Moreover, all infants showed very short fixations during the presentation of the static images. Corroborating previous research, the gap and overlap disengagement latencies correlated with individual mean fixation durations, evidencing the influence of inhibitory control on gaze allocation. These findings form the basis for building the first computational model of fixation durations in early infancy, which will be grounded on the CRISP adult model (Nuthmann et al, 2010; Psych.Rev). The infant model will aim to capture developmental changes in fixation durations enabling valuable insights into oculomotor control in typically developing children.

Acknowledgement: Marie Curie Fellow

36.533 **Bimodal Affective Stimuli Do Not Always Enhance Infant's Rule Learning: Congruency And Relevance Matter Too**

Chia-huei Tseng[1](CH_Tseng@alumni.uci.edu), Yuen Ki Ma[1], Hui Mei Chow[1]; [1]Department of Psychology, The University of Hong Kong

Tsui and Tseng (2011) found bimodal presentation of grammar-like rules (AAB) helps 8-10 month preverbal infants to learn otherwise when the rule is presented with visual presentation of emotional cartoon faces alone (happy-upset-happy faces) or auditory presentation of corresponding emotional sounds (laughing-crying-laughing) alone. But bimodal facilitation did not apply when geometry shapes accompanied by recorded syllables. We investigated what constitutes the difference in two experiments. In Experiment 1, we tested whether visual and audio congruency was critical by habituating 15 infants to the same AAB rule with emotional cartoon faces (e.g. happy face) coupled with incongruent emotional sounds (e.g. crying sound). We did not find difference between novel and learnt rules at dis-habituation looking time as learning evidence. In Experiment 2, we tested whether emotional content is essential for bimodal facilitation by employing an emotionless cartoon face speaking syllables to habituate seventeen 8-10-month-olds with the same AAB rule. At dis-habituation, infants looked longer significantly at novel rules (ABB and ABA), demonstrating successful acquisition of the habituated rule. Our results indicate that relevancy and congruency in audio-visual pair both matter to facilitate infants' abstract rule learning. Syllables associated from a human face are better than when associated with arbitrary visual shapes. Infants' learning effect is compromised when the emotional congruence of the audio and visual stimuli is reduced. It suggests that an object-based cross-sensory integration occurs before the abstract rule is extracted from bimodal presentation.

36.534 **Anticipatory Eye Movements, Pupil Size Changes, and Long-Term Memory in Infants**

Audrey Wong Kee You[1](audwky@yorku.ca), Scott Adler[1,2]; [1]York University, [2]Centre for Vision Research

Research has demonstrated that young infants can retain event information in memory over the long term. Other studies have demonstrated that they are also capable of forming expectations and exhibiting anticipatory eye movements for the spatial, content, and temporal parameters of future events. Theories have suggested that these abilities highlight our memory's function of providing a foundation upon which expectations for future events formed. This study aimed to assess this hypothesis by investigating the relation between long-term memory and expectation formation in 3-month-old infants. Infants viewed spatially predictably alternating (left-right) sequences of shapes in which the color content remained invariant on one side but varied on the other; a stimulus sequence for which infants have previously been shown to form an expectation for the specific invariant color content. After a delay of 24 hours, infants were tested with either a change in the invariant colour combination while keeping its spatial location unchanged (color-change condition), a change in the location of the invariant stimuli with the particular color combination remaining unchanged (spatial-change condition), or with no change to any aspect of the sequence (no-change condition). Infants' level of anticipatory eye movements as well as the latency of reactive eye movements were measured on both test days. Changes in pupil size during encoding on Day 1 and retrieval on Day 2 were also measured. Results indicated that infants discriminated any change in the stimulus sequence on Day 2 relative to Day 1, indicating that they encoded and remembered this information from Day 1. These findings support the theory that visual expectation processes are related to mechanisms of long-term memory in infancy. In addition, this study reveals the potential for assesssing eye movements and pupil size to examine long-term memory mechanisms in infants.

36.535 **The Santa Barbara Solids Test as a predictor of spatial visualization in older adults**

Shannon Bailey[1](shannon.bailey@ucf.edu), Alexis Dewar[1]; [1]Psychology Department, College of Sciences, University of Central Florida

The Santa Barbara Solids Test (SBST) is a new measure of spatial ability which tests skills that are necessary for many Science, Technology, Engineering, and Math (STEM) disciplines. The SBST consists of geometric forms that are bisected by a plane. The participant must determine the nature of the bisection by distinguishing which one of the multiple choice 2D shapes would be the result from the bisection of the form. The success of the participant requires the ability to encode visual information accurately and visualize the manipulation of the stimuli. The SBST has been validated with college-age students, but should be tested in other populations for broader use. Because spatial visualization is shown to decline with age (Verhaeghen & Salthouse, 1997), the current study tested the SBST in older and younger adults to compare the efficacy of the novel measure. Twenty-seven participants, 17 Young Adults (18-34) and 10 Older Adults (64-82), completed the SBST and two other measures of spatial visualization (The Paper Folding Test and an adaptation of the Visualization of Views Test). Results were consistent with previous studies using the SBST, showing that the SBST correlates with other measures of spatial visualization (Cohen & Hegarty, 2012). The younger adults marginally outperformed older adults on the SBST. Furthermore, results indicated that older adults in a STEM field performed better on the SBST than older adults in a Non-STEM discipline, and the SBST could be used as a measure of spatial visualization.

36.536 **Age-related differences in the control of braking**

Zheng Bian[1](bianz@ucr.edu), George Andersen[1]; [1]University of California, Riverside

Previous studies have found that observers used tau-dot to regulate braking (Yilmaz & Warren, 1995; Fajen, 2005). Braking performance was also affected by other sources of visual information, such as global optical flow and edge rate (Fajen, 2005). In the current study we examined age-related differences in the use of visual information in regulating braking. Twelve younger (mean age = 21.2) and twelve older observers (mean age = 71.6) participated in the study. 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. The roadway had either no texture or black-and-white checkerboard texture with various densities. During the first 10 seconds, the observers did not have control over the brake. Ten 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 distance from the stop signs (40m, 45m, or 50m), and the texture density on the ground (no texture, 32×16, 32×32, or 32×64) were manipulated. The texture density was blocked and counterbalanced across observers in each age group. The mean stop distance relative to the stop signs, the 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 than younger observers. In addition, older observers, as compared to younger observers, tended to regulate tau-dot more frequently at values larger than -0.5 and less frequently at values smaller than -0.5. These results, taken together, suggest that older observers may use a more conservative strategy to control braking in order to avoid collisions.

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36.537 **Age-related differences in distance perception during remote tool-use**

Matthew Costello[1](mccostel@iusb.edu), Christopher Davoli[2], Nicholas Panting[1], James Brockmole[2]; [1]Department of Psychology, Indiana University South Bend, [2]Department of Psychology, University of Notre Dame

Perception can be surprisingly affected by bodily factors. For instance, broad-shouldered subjects report doorway widths to be narrower than do narrow-shouldered subjects (Stefannuci & Geuss, 2009), and weight encumbrance can increase slope estimates (Proffitt, 2006). Perceptual alterations are also evident when perceivers interact with objects. For instance, Davoli, Brockmole, and Witt (2012) found that participants judged distant objects to be closer if they could illuminate them with a laser pointer. Critically, the vast majority of studies of embodied perception have studied young adults, and thus the question of whether or how aging may alter embodied perception has been underexplored. Given the bodily and neurological changes that accompany aging, it is reasonable to suspect that perception should reflect corresponding age-related differences. Recent work suggests that older adults have a diminished neural flexibility for incorporating tools into their body schema compared to younger adults (Bloesch & Abrams, 2012). Thus, in the present study, we examined whether using a laser pointer to interact with distant objects (cf. Davoli et al., 2012) would affect distance perception differently in older compared to younger adults. Younger (18-30 years) and older (60-79 years) adult participants estimated the distance to a target at various locations along a 95-ft hallway while either illuminating the target with a laser-pointer or while pointing at the target with an inert metal baton.

Replicating previous work, we found that younger adults judged targets to be closer when using a laser-pointer compared to pointing a metal baton. Critically, however, the distance judgments of older adults did not depend on whether they used a laser-pointer or pointed a baton. These findings indicate that perception of distance is less influenced by one's capacity for remote interaction as the perceiver ages, and suggest that embodied effects revealed in perception are not invariable across the lifespan.

36.538 **Does better performance mean better learning in visuomotor tasks?** Mark Mon-Williams[1](m.mon-williams@leeds.ac.uk), Rachael Raw[1], Richard Allen[1], Richard Wilkie[1]; [1]Institute of Psychological Sciences, University of Leeds

Introduction: Is there a direct relationship between poor visuomotor performance and impaired sequence learning? One index of reduced performance is increased movement duration caused by the necessity for visual feedback error correction. Visual feedback correction mechanisms use cognitive resources, thus we conjectured that working memory capacity will be reached more quickly when sequence elements require more visual correction. Methods: Specialist software presented visual stimuli and recorded movement kinematics. Participants learned a sequence of movements made between a central target and one of eight target locations shown on a tablet PC screen. Experiment 1 explored visuomotor performance and error corrections in younger and older adults in an aiming movement task. Experiment 2 studied visuomotor learning of a sequence of aiming movements in these populations. Experiment 3 tested the visuomotor sequence learning in younger and older participants when using their preferred and non-preferred hands. Results: Experiment 1 confirmed reduced visuomotor performance in older adults, and the older adults exhibited greater visual error corrections when carrying out the aiming task with no learning requirements. Experiment 2 found that older adults were poorer at learning the complex sequence of aiming movements. Experiment 3 showed that both age groups were worse at sequence learning when using their non-preferred hand. Conclusions: Our results suggest reduced visuomotor performance can impact negatively on the processes necessary for learning new sequences beyond the limits imposed by an individual's cognitive capacity. We have developed a formal model that predicts the number of elements learned as a function of visuomotor skill level. While the present work examined some of the deficits associated with old age, the findings also have implications for other groups that experience visuomotor deficits (e.g. developmental coordination disorder).

Acknowledgement: Medical Research Council

36.539 **Peripheral Motion Contrast Thresholds as a Predictor of Older Drivers' Performance During Simulated Driving** Heather Woods-Fry[1](hwood053@uottawa.ca), Misha Voloaca[1], Charles Collin[1], Steven Henderson[2], Sylvain Gagnon[1], John Grant[3], Ted Rosenthal[3], Wade Allen[3]; [1]University of Ottawa, [2]Transportation Safety Board of Canada, [3]Systems Technology Inc.

Older drivers have an increased rate of automobile crashes per kilometer driven, likely due in part to age-related declines in motion perception. Our research group has developed the "Peripheral Motion Contrast Threshold test" (PMCT) test and, more recently, the "Rapid PMCT" test as measures of peripheral motion sensitivity. Results from these tests have been shown to correlate strongly with indicators of driving performance in older individuals. In the current study, we investigated how effective the PMCT and RPMCT tests are at predicting driving safety on a driving simulator. We tested 26 younger drivers and 26 older drivers in the STISIM high fidelity driving simulator. Performance was measured in terms of number of collisions and minimum distance of approach to hazards. The PMCT presents participants with Gabors (0.4 cpd, 13.75°/s drift) at one of four locations 15° from fixation, and uses method of limits to measure contrast threshold. The RPMCT presents the same stimuli positioned 15° to either side of fixation, and uses a 2AFC variation on the ascending Bekesy Method. Results from the older drivers show a positive correlation between PMCT & RPMCT and collision rate.. There was also a significant negative correlation between PMCT & RPMCT measures and minimum distance of approach to hazards. Our research demonstrates the ability of both measures to effectively predict the occurrence of hazardous driving under simulated conditions in older subjects.

Perception and action: Models, adaptation

Sunday, May 12, 2:45 - 6:45 pm

Poster Session, Vista Ballroom

36.540 **Me - Not Me - Or In Between? Comparison of Causal Inference Models for Agency attribution in goal-directed actions** Tobias F Beck[1,2,3](tobias.beck@uni-tuebingen.de), Carlo Wilke[1], Barbara Wirxel[1,3], Dominik Endres[1,2,3,4], Axel Lindner[1,3], Martin A Giese[1,2,3,4]; [1]Dept. of Cognitive Neurology, Hertie Institute for Clinical Brain Research and Centre for Integrative Neuroscience, Tübingen, Germany, [2]Section Computational Sensomotorics, [3]Bernstein Center for Computational Neuroscience Tübingen, [4]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 [2,3] and the accuracy of integrated signals [4,5]. Attribution of percepts to consequences of own actions should thus depend on the consistency between internally predicted and actual visual signals, but what does the data support: binary (me vs not me)[6] or continuous (partially me) attribution? Methods. To examine this question, we used a virtual-reality setup to manipulate the consistency between pointing movements and their visual consequences and investigated the influence of this manipulation on self-action perception with visual stimuli of varying precision. In previous work we showed that a Bayesian causal inference model, assuming a binary latent agency variable controlling the attributed influence of the self-action on perceptual consequences [2,3], accounted for the empirical data [6]. Here, new models assuming a continuous variable for attribution of the visual feedback to own action are presented and their performance predicting the empirical data evaluated and compared to the binary model [2,3]. The models assume both visual feedback and internal estimate are directly caused by the (unobserved) real motor state. Results and Conclusion. The models correctly predict empirical agency ratings, showing attribution of visual signals to self-action for small, and stronger reliance on internal information for large deviations. We discuss the performance of these causal inference models, applying methods for model comparison. [1] Wolpert et al., Science, 269, 1995. [2] Körding et al., PLoS ONE, 2(9), 2007. [3] Shams & Beierholm, TiCS, 14, 2010. [4] Alais & Burr, CurBio, 14, 2004. [5] Burge et al., JVis, 8(4), 2008. [6] Beck et al., JVis, 11(11): 955, 2011.

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36.541 **Learning and optimal inference in a novel spatial localization task** Vikranth R. Bejjanki[1,2](bejjanki@princeton.edu), David C. Knill[1], Richard N. Aslin[1]; [1]Center for Visual Science and Department of Brain and Cognitive Sciences, University of Rochester, [2]Princeton Neuroscience Institute, Princeton University

To estimate the location of a visual target, an ideal observer must combine what is seen (corrupted by sensory noise) with what is known (from prior experience). Bayesian inference provides a principled method for optimally accomplishing this. Here we provide evidence from two experiments that observers combine sensory information with complex prior knowledge in a Bayes-optimal manner, as they estimate the locations of targets on a touch screen. On each trial, the x-y location of a target was drawn from one of two underlying distributions (the "priors") centered on mean positions on the left and right of the display, and with different variances. The observer, however, only saw a cluster of dots normally distributed around that location (the "likelihood"). Across 1200 trials, the variance of the dot cluster was manipulated to provide three levels of reliability for the likelihood. Feedback on observers' accuracy in each trial was provided post-touch using dots representing the touched location and the true target location on the screen. In Experiment 1, consistent with the Bayesian model, observers not only relied less on the likelihoods (and more on the priors) as the cluster of dots increased in variance, but they also assigned greater weight to the more reliable prior. In Experiment 2, we obtained a direct estimate of observers' priors by additionally having them localize the target in the absence of any sensory information. We found that within a few hundred trials, observers reliably learned the true means of both prior distributions, but it took them much longer to learn the relative reliabilities of the two prior distributions. In sum, human observers optimized their performance in a novel spatial localization task by learning the relevant environmental statistics (the two different distributions of target locations) and optimally integrating these statistics with sensory information.

Acknowledgement: This work was supported in part by NIH HD037082 and by the Office of Naval Research (MURI program).

36.542 **Response to perturbation in constant tau-dot versus constant proportional rate models of visually guided braking**

Aaron Fath[1](ajfath@indiana.edu), Brian Marks[2], Geoffrey Bingham[1]; [1]Indiana University, [2]University of Maryland Baltimore County

Introduction. We performed simulations to evaluate two models of visually guided braking, in which the deceleration was capped, as might happen when a car brake fails. The two monocular tau models were (1) constant tau-dot control (e.g. Yilmaz & Warren (1997)), and (2) constant proportional rate control (e.g. Anderson & Bingham (2011)). Methods. For each model, we evaluated a system of ordinary differential equations, in which the respective control strategies were to hold either tau-dot or tau-dot/tau constant. However, when a deceleration cap was imposed, these could not be held strictly constant. The models were adjusted to allow change in these visual control variables using an abstract mass-spring model whose equilibrium position was the desired value of the control variable. Our simulations were carried out in Matlab. In the simulations, the initial distance from the target was 350 cm and the initial velocity was −100 cm/s, so that the initial time-to-contact was 3.5 s. Results. We show color plots of the final velocity at target acquisition for the two models, for values of the control variable on the x-axis, and the deceleration cap on the y-axis. Each plot shows 100 x 100 = 10,000 total simulation runs. The range of values shown for the control variables was consistent with experimental data in previous studies. A velocity value close to 0 is desirable for soft contact, and higher values indicate a collision. The proportional rate strategy showed a large region of parameter space over which contact was achieved with low or zero velocity, while the constant tau-dot strategy did not recover well from an imposed cap on the deceleration. Conclusion. The proportional rate control model exhibited better stability than did the constant tau-dot model. We also show that these results are the same when disparity tau (Anderson & Bingham, 2011) is used.

36.543 **Reaching With Altered-Grip-Spans: How Altering Effectivities (But Not Affordances) Influences Behavior**

Emel Gencer[1](egencer@indiana.edu), Winona Snapp-Childs[1], Mark Mon-Williams[2], Geoffrey Bingham[1]; [1]Indiana University, [2]University of Leeds, UK

Introduction: Mon-Williams and Bingham (2005; 2011) discovered the affordance properties of objects that determine the spatial structure of reach-to-grasp movements. They formulated a model containing a single free parameter and variables that were determined by object (maximum-object-extent or MOE) and actor (maximum-grip-span or MGS) properties. Snapp-Childs et.al (2011) showed the generality of this model testing people with different MGS. In the current experiments, we investigated the effect of altering effectivities (relevant actor properties) by restricting (Experiment 1) or extending (Experiment 2) MGS. Method: Participants reached quickly for objects that varied in object-width (3, 5, 7cm) and contact-surface-size (1, 2, 3cm), thus in MOE. The levels of perturbation were: 1) no restriction/extension (no device), 2) no restriction/extension (with device on-hand), 3) 20% MGS restriction/extension, and 4) 35% MGS restriction/extension. Results: The model predicted that the safety-margin at the time of maximum-grasp-aperture (MGA) should be 34% of the available-span (MGS-MOE). With no adaptation to MGS perturbations, the expected mean percentages were: 3) 49%, 4) 73% for 20% and 35% restrictions and 3) 24%, 4) 21% for 20% and 35% extensions, respectively. The actual mean percentages were, for Experiment 1: 1) 33%, 2) 30%, 3) 35% (significantly different from no adaptation ($t(178) = 6.8$, $p < 0.001$)), 4) 40% (significantly different from no adaptation ($t(178) = 10.1$, $p < 0.001$)) and for Experiment 2: 1) 33%, 2) 29%, 3) 24% (not significant ($t(160) = 0.1$, $p > 0.9$), 4) 21% (not significant ($t(160) = -0.4$, $p > 0.6$). Continuous adaptive trends were evident over trials with restricted grip-spans, but not with extended grip-spans. Conclusions: When the effective size of their hand was reduced, participants exhibited adaptation to renormalize their grasping, essentially preserving the form and scaling of the behavior, but when the effective size of their hand was increased, they exhibited no adaptation.

36.544 **Using Dynamical Simulations to Quantify Affordances in the Task Space for Throwing to Hit Distant Targets**

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Introduction: Throwing to hit distant targets requires perception of target distance and height. This information must then be used to control both release angle and speed of the projectile. These two action parameters trade off to allow target hits. Some regions of the parameter space yield greater latitude in parameters that yield a hit, affording the most reliable performance. Do expert performers perceive this affordance to operate in these more stable regions? Methods: We tested expert throwers in two studies. Participants threw balls to hit a 4ft x 4ft vertical target. In Experiment 1, we manipulated target distance (5m, 10m, 15m) and height (1m, 1.5m, 2m). In Experiment 2, we manipulated target distance (5m, 10m, 15m), orientation (vertical, horizontal), and vision (monocular, binocular). We performed dynamical simulations of hit/miss across a wide range of release parameters to map stability in the task space. We then mapped the experts' performance within this space. Results: For vertical targets, release speeds were high and scaled with distance. Release angles were low and scaled with both distance and height. The horizontal target then forced experts to throw high and slow, which they readily did. Monocular vision only affected throws to vertical targets; poorer resolution of distance yielded slower throws compensated for by increased angles. Dense simulation of the parameter space allowed us to quantify the affordances. Experts do operate in regions of the space with optimal stability (i.e. hits over wide variation in release angle). Conclusion: The dynamics of throwing to distant targets yield a task space specified in terms of two action parameters, release angle and speed, that determine successful action. Mapping the structure of this space reveals regions affording reliably successful performance. Expert throwers exhibited sensitivity to this affordance, performing within these more stable regions.

36.545 **Learning of likelihoods for Bayesian computations**

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Introduction: The statistical distributions of the quantity that has to be estimated (called prior), and currently available sensory information about that (called likelihood), are the basis of all Bayesian models. Performance of our sensory systems could also change over time and it also depends on the context such as the properties of the stimulus source. Our brain thus has to constantly estimate the reliability of our sensory systems. Although many studies have shown that priors are learned from experience, little is known about the learning of likelihood uncertainty. Here, we show that human subjects can learn the uncertainty of likelihood in a context dependent way (e.g. red is associated with more uncertainty than green) and correctly generalize this knowledge to the combination with new priors. Methods: We used a sensory-motor task in which subjects estimated a location ("hidden coin") from a splash that it caused. The prior of coin locations was displayed explicitly, and the width of the distribution of the splashes around the coin (likelihood) was cued by the splash color. To show the subjects actually learned the likelihood, we examined whether the learned (color cued) likelihood generalizes to a new prior. Results: We found that subjects relied more on visual splashes when the color indicated that the splashes were more reliable; the subjects learned to switch between different likelihoods depending on the context. When the prior is changed, the subjects adjusted how much they relied on the cue vs the new prior even for the cues associated with the color that was not used during the learning of the new prior. Conclusion: We showed that human subjects could learn the quality of sensory information (likelihood) in a context dependent way and combine the learned likelihood with different priors to make efficient estimations.

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36.546 **Are Radiologists Ideal Observers? --Evidence from Observer Studies in Radiology**

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In the past fifty years, a large number of ROC curves have been generated by radiologists reading medical images. There is a common belief that human ROC curves should generally be convex and that non-convex ROC curves are caused by some imperfections in the measurement procedures, for example, the limited number of images read by observers, poor experimental design and/or curve fitting errors. We propose an ideal observer (IO) model to describe a radiologist's performance based on the fact that a convex ROC curve corresponds to one unique pair of likelihood ratio (LR) distributions. We define an equivalent IO (EIO) as the one who has the same performance as the human observer, as characterized by an ROC curve. To measure the LR distributions of the EIO, we formalize experimental design principles that force the observers to act rationally based on

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von Neumann and Morgenstern's axioms. We show that human observer study design refinements in radiology, although motivated by empirical or practical principles, implicitly enforce rationality and result in reasonably convex ROC curves. EIO theory allows us to model the human observer as an ideal observer. It also suggests that while the human observers are not optimal or cannot fully use the statistical information in medical images, at some level they can be rational or ideal in using the limited information that they are able to extract from the images for decision making.

36.547 **Examining the Neural Correlates of Updating Mental Representations**

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The ability to build mental models is critical for goal setting, decision making, and predicting environmental contingencies. Much is known about how unsupervised, passive integration of regularities in visual, auditory, semantic, and/or kinesthetic information in the environment influences goal-directed behavior. However, less is known about how such mental models change in response to expanded information sets or novel observations. In the current study we examined this process, termed representational updating, using functional magnetic resonance imaging to elucidate the brain networks that support updating. Participants played a visual analogue of the popular children's game of rock, paper, scissors against a computer that utilized multiple strategies that participants' had to exploit in order to maximize success. Behavioral results indicated that participants quickly and reliably adjusted their play choice to exploit the biases in the computer's play strategy in a way that mimicked probability matching behavior. Imaging results revealed a network of areas activated during these changes in play including cingulate cortex (both posterior and anterior cingulate), bilateral superior temporal gyrus, middle frontal gyrus, and the precuneus. Taken together, these results suggest the presence of a cortical network that supports the updating of mental models consisting of areas involved in error monitoring, statistical learning, and cognitive control. Furthermore, areas in this network (namely the STG) are commonly lesioned in neglect patients, who show deficits in updating on similar behavioral tasks.

Acknowledgement: NSERC, CIHR

36.548 **Towards a biologically-inspired vision system for the control of locomotion in complex environments**

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We investigate the perceptual principles responsible for the visual control of human locomotor behaviors by modeling the neural mechanisms of human vision. We have built an empirically-grounded perception and action system by coupling a biologically plausible computational model of motion processing in the dorsal stream of the visual cortex (Jhuang et al., ICCV, 2007) to a cognitively valid locomotor control model (Warren & Fajen, In Fuchs & Jirsa, Coordination, 2008). Here we report on initial results of this integration of the two models and show that the coupled system accounts for human data for steering to a goal while avoiding obstacles (Warren & Fajen, In Fuchs & Jirsa, Coordination, 2008). We further report on a recent extension of the vision model to also include the detection of motion boundaries, binocular disparity as well as shape and color information in addition to motion energy. We simulate an agent moving in complex virtual environments using a perception-action loop that includes the vision model, the locomotor control model, and the environment. Visual cues are successfully used as input to the locomotion model to modulate the activation of control laws, leading the agent to avoid obstacles while steering to its goal. As the agent travels through its environment, the virtual optic flow from the agent's perspective changes, which in turn modifies the detected visual cues. The agent is thus coupled to its environment through information and action, and locomotor trajectories are emergent (Warren, Psychological Review, 2006). We use different degrees of realism and complexity for the virtual scenes, from a few to many objects, and simple to complex textures, to demonstrate the validity of the approach.

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36.549 **The impact of intention, action, and learnt contingency on visual perception.**

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While visual perception is guided by the image cast on our retinas, there are many other influences at play. The process of constructing a percept is also influenced by a myriad of contextual cues. For example, evidence is emerging for a role of action in the formation of percepts (Maruya, Yang & Blake, 2007 Psych. Sci.). In the present study, we investigate whether this interaction between action and perception is plastic rather than simply due to innate biases. During training, subjects' arm movements were associated with a particular unambiguous appearance of either a rotating necker cube or dot sphere. During testing, the cues, which disambiguated the stimuli, were removed and subjects were required to move their arm and make a judgement about the direction of perceived rotation. Subject responses revealed a reliable effect of arm movement on perceived direction of rotation, and that this was consistent with the direction seen during training. Importantly, we were able to demonstrate learning with participants forming arbitrary left-left, left-right, left-up, left-down contingencies between movement and perceived stimulus rotation. Earlier studies on visual perception have argued that arbitrary visual cues can be recruited to aid formation of a visual percept simply through a process of paired association between a known 'trusted' cue and the new arbitrary cue (Haijiang, Saunders, Stone & Backus, 2006 PNAS). Interestingly, not all cues can be recruited, regardless of whether they are reliable estimators of the perceptual event (Jain, Fuller, & Backus, 2010 PLoS). Our results suggest that cue recruitment provides robust effects in the multimodal domain of visuomotor behaviour.

36.550 **The Effect of Action on Perception is Really the Effect of Information on Memory**

Bruce Bridgeman[1](bruceb@ucsc.edu), Sabine Blaesi[1]; [1]Department of Psychology, University of California, Santa Cruz

Tossing a marble into a hole changes memory of the hole's size; it seems larger if the toss was successful than if it was unsuccessful. This has been attributed to the effect of action on subsequent perception or memory. We ask what the action provides: Is it feedback from the motor act or only the information provided by the action that alters memory of hole size? We find that perceived difficulty alone changes remembered goal characteristics, with no changes in the stimuli or the task. Observers are given a marble, shown a hole, and told that the throwing task is difficult, that 90% of participants fail, or that it is easy, that 90% of participants succeed. The hole is then covered and its size is judged. Those who were told that the task is easy judge the hole to be significantly larger than it is, while those told that the task is difficult make judgements not significantly different from the veridical size of the hole. Size is given as a choice among seven previously memorized alternatives. When the observers subsequently attempt to throw the marble into the hole, their success rate does not depend on their choice or what they were told about the difficulty of the task, showing that their size estimate affects memory but not action. Our task shares several characteristics with other tasks used to test the effects of action on perception, such as golf putting or football punting: the target of the action is exocentric, accuracy is assessed spatially, and there is a ballistic component to the action. Our measure differs because target size is judged while fixating visually on the target, without manipulating another object for comparison.

36.551 **The Relative Influences of Form and Action Information on Object Identification and Action Production**

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Past research has shown that visually presenting an object can activate associated structural and functional information. We contrasted the relative impacts of form and action information carried by verbal labels in a visual identification task and an action production task. We paired eight novel graspable objects with novel actions and identified each object/action pair with a verbal label that carried information that was congruent or incongruent with either the form of the object or the action associated with the object. We then presented participants with sequences of learning trials where participants saw each object/action/name triad, and test trials where participants were presented with individual objects. Furthermore, we either asked participants to imitate the actions during learning trials, or to only watch the action demonstration. In Experiment 1, participants visually identified each object using its label (no action was produced), and in Experiment 2, we asked participants to produce the action associated with each object (no naming was required). In both experiments, using labels carrying congruent information facilitated performance. Importantly, labels carrying information congruent with an object's form facilitated performance to a greater extent than using labels carrying information congruent with an object's action. Learning condition did not impact the results. Interestingly, only action information seemed to drive error patterns – when labels were incongruent with an object's action, participants tended to produce errors associated with label information. These findings confirm that information associated with verbal labels is recruited when these are used to identify novel objects, and that when congruent, this information can facilitate naming and action perfor-

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mance. Importantly, this finding indicates that form information associated with verbal labels may carry more weight than action information, even when the task is to perform actions and naming is not required.

Acknowledgement: Marjorie-Young Bell Faculty Fellowship (first author), Natural Sciences and Engineering Research Council of Canada (third author)

36.552 Deciding When To Act: Sub-Optimal Selection Strategies In Motion Estimation

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Many commonplace activities (e.g. waiting for a gap in traffic) involve deciding to act upon one of a series of events. In such circumstances, the probability of acting successfully must be estimated and weighed against the probability of success for subsequent events. Here, we examined whether observers can maximise gain in a task requiring the selection of a single entry in a finite series, for use in a subsequent motion estimation task. In a series of training trials, observers were presented with a dot moving from the centre to the edge of a circle. Dot movement was randomly selected from a von Mises distribution, with spread K. The dot disappeared before reaching the edge of the circle, and participants were asked to 'catch' the dot by estimating the point at which they believed it would hit the circle's edge. The probability of catching a dot was measured at a range of K-values. To examine selection strategies, participants were required to attempt to catch a single dot from a set of seven. The seven dots were presented in sequence, and observers were unaware of the K-values used in each set. For each dot, observers had the option to attempt a catch, or to skip and be presented with the next item in the set. Dots could not be returned to once skipped. Results were compared to a Maximum Expected Gain model, which uses observer performance in training to define the optimal selection strategy. Contrary to the strategy adopted by observers, this model predicts that observers should typically wait until later in the set to act, skipping earlier items. Observers instead chose lower than predicted K-values, selecting to act earlier in the set. These results suggest that the ability to maximise gain in perceptual tasks may be limited by task complexity.

36.553 Adaptation to temporal delays generalises to new circumstances but is task-specific

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People readily intercept moving targets with a delayed visual representation of their hand. Seeing the representation pass the target is enough to perform better on subsequent trials, so they are not just speeding up in response to the visual representation being less far than they expected. Here we examine the specificity of such sensory-motor adaptation. We examined generalisation to a different task (pursuing a moving dot with the unseen hand), to a new aspect of the same task (moving through a gap on the way to the target), and to slight modifications of the same task (starting the movement at a different position). The pursuit task was measured in separate sessions before and after adaptation. During adaptation, subjects intercepted targets that were moving to the left or right at various speeds. The delay between the position of the hand and that of its representation was gradually increased to 200ms. Delayed visual feedback was provided when the hand started 5 or 20 cm closer than the target's path. No feedback was provided when it started 10 cm closer. Subjects adapted to the delay. This adaptation transferred to the 10 cm movements. There was no transfer to the pursuit task. In another session, subjects had to pass through a moving gap on their way to intercept the target. They only saw the visual representation of the hand as it passed the target. Nevertheless, they synchronized the delayed feedback with the gap. We propose that our subjects learnt to control the delayed representation of the hand (to use a tool), rather than learning to make specific movements (which would not transfer to a different starting point or to passing through a gap) or adjusting the haptic sensation of their hand to match what they see (which would have transferred to the pursuit task).

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36.554 Learning and the Role of Visual Information in Calibrating the Forces of Throws

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To coordinate ballistic actions with visual targets forces need to be calibrated against distances. In 2 studies adults threw a baseball with an underhand toss to land on a visible target that was 12m away. Subjects were equipped with a sound system so they could not hear where the ball landed. They wore liquid crystal goggles and were fitted with a hand-pressure switch, so the transparent goggles went opaque when the ball left the hand. There was no information about whether throws were long or short, so throw distances indicate the target-to-force calibrations brought to the task, not ones fine-tuned to ball or target. However, people could monitor differences in intended forces in the efferent copy and the feedback forces for each throw, and improve the consistency of their throw-forces from trial to trial. In Experiment 1 people tossed the ball 100 times -- everybody threw short, averaging 9.5m throws to the 12m target, with some averaging 3-4m throws! The throw distances did not change across the trials. People were unaware of their errors – they were shocked in follow-up interviews. Believing their throws were accurate, they worked to become more consistent, monitored their proprio-kinesthetic force feedback from trial to trial, and threw with significantly more consistency during the second block of trials compared with the first. Study 2 was similar to Study 1, except half the subjects could see where the balls landed. Anova showed both groups threw too short during the early trials; those without vision continued to throw short, but those with vision threw further and further with practice. Continuing work is focused on kinematic analysis of the release-angles and release-forces of the throws, and on vision-substitution applications to the throws of athletes who are blind.

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36.555 Manual tracing facilitates comparison of linear trends from multiple scatterplots

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Performing an action enhances our perception of events related to that action (Shutz-Bosbach & Prinz, 2007). Here, we show that manual tracing of a scatterplot can improve visual trend perception in a realistic task where participants are comparing performance of 4-8 companies. Four, six, or eight scatterplots (representing companies A, B, C, D, etc.) were sequentially presented (1 sec per plot) on an iPAD. In the tracing condition, participants traced (with their index finger) what they thought indicated the line of best fit for each scatterplot. In the passive condition, participants visually estimated the linear trend for each scatterplot without tracing. After the last scatterplot was presented participants indicated which company had the fastest growth by touching the appropriate button. We measured RTs (from the disappearance of the last scatterplot to response) and accuracy (frequency of choosing the fastest growing company). When 4 or 8 scatterplots were presented, tracing did not produce a clear gain in performance; although tracing reduced RTs it increased errors. In contrast, when 6 scatterplots were presented, tracing improved performance by reducing RTs without increasing errors. Furthermore, in the tracing condition, those who traced linear trends more accurately (i.e., slopes of their traced lines being more similar to those of the actual regression lines) made fewer response errors when 4 or 6 scatterplots were presented but not when 8 scatterplots were presented. Thus, the perceptual gain from manual tracing has capacity limits. Taken together, these results suggest that (1) accurate tracing of trend lines from scatterplots improves encoding of linear trends with a capacity limit of about 6, and (2) tracing facilitates mental comparison of linear trends when working memory load is moderate (6 scatterplots). Our results suggest that action enhances visual perception of statistical trends in a realistic task that requires working memory.

Acknowledgement: National Science Foundation Graduate Resarch Fellowship

36.556 Common Coding Not Supported: Expert and Novice Throwers Viewing Point-Light Displays of Self vs Other's Throwing Motions to Judge Target Locations

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Introduction: The Common Coding Theory (Prinz, 1997; Hommel et al., 2001) suggests that perception and action share a common representation and hypothesizes accordingly: 1) people should better perceive motions that are produced by their own action; 2) people should better perceive actions at which they are skilled. We now test these hypotheses using point-light displays of experts throwing to hit targets at different distances and heights. Methods: Using videos of 6 experts throwing to hit targets at 3 distances (5m, 10m, 15m) and 3 heights (.5m, 1m, 1.5m) 5 times each, we created 45 point-light displays for expert and novice throwers to judge the distance and height of targets. Point lights were attached to 7 major joints of the thrower including the ball and only throwing motion was displayed up to ball release. Expert and novice throwers judged displays of throws by other experts. Experts also judged displays of themselves. Results: All observers were well above chance in judging distance (54.8%±8.1>33.3%), height (51.4%±8.6>33.3%) and both (28.6%±9>11.1%). A repeated-measures ANOVA on expert judgments testing identity (self, other) was significant for distance ($F_{1,5} = 8.66$, $p<0.05$, self: 52%, other: 62%), and for height ($F_{1,5} = 9.31$, $p<0.05$, self: 48%, other: 56%). Other was always judged better than self! A factorial ANOVA on judgments of other testing skill level (expert, novice) was significant for distance ($F_{1,10} = 9.55$, $p <0.01$, experts: 62%, novices: 50%), but not for height ($p>0.05$, experts: 56%, novices: 50%). Conclusion: The first hypothesis was rejected because experts judging other were better than they judging self. The second hypothesis was only partly supported because experts judging other were better than novices judging other only in respect to distance, not height.

Monday Morning Talks

Motion: Biological, optic flow

Monday, May 13, 8:15 - 9:45 am

Talk Session, Royal Ballroom 1-3

Moderator: Simon Rushton

41.11, *8:15 am*

Recovery of biological motion processing and network plasticity after cerebellar lesion

Arseny Sokolov[1,2](arseny.sokolov@med.uni-tuebingen.de), Michael Erb[3], Wolfgang Grodd[4], Marcos Tatagiba[1], Richard Frackowiak[2], Marina Pavlova[5,6]; [1]Department of Neurosurgery, University of Tübingen Medical School, Germany, [2]Département des Neurosciences Cliniques, Centre Hospitalier Universitaire Vaudois (CHUV), Lausanne, Switzerland, [3]Department of Biomedical Magnetic Resonance, University of Tübingen Medical School, Germany, [4]Department of Psychiatry, Psychotherapy and Psychosomatics, University Hospital Aachen, Germany, [5]Department of Pediatric Neurology and Child Development, Children's Hospital, University of Tübingen Medical School, Germany, [6]Institute of Medical Psychology and Behavioral Neurobiology, MEG Center, University of Tübingen Medical School, Germany

Visual body motion perception is essential for social competence and everyday life activities. The left lateral cerebellum is involved in visual biological motion processing and interacts with the right superior temporal sulcus, STS (Sokolov et al. Neuroimage 2012), a key structure within the action observation network. Lesions to the left lateral cerebellum may cause deficits in body motion perception (Sokolov et al. Cereb Cortex 2010). Yet alterations in sensitivity to body motion and the underlying neural network after cerebellar tumor removal remain unknown. Psychophysical assessment of visual sensitivity to point-light biological motion was conducted before, and 8 and 24 months after neurosurgery in a patient SL with left cerebellar dysplastic gangliocytoma (WHO grade I), and in six healthy controls. Functional magnetic resonance imaging (fMRI) was used to assess postoperative activity and connectivity during visual body motion processing. Preoperative visual sensitivity to biological motion in patient SL was significantly lower than in healthy matched controls. Sensitivity substantially improved at 8 months and approached the level of controls at 24 months after neurosurgery. As compared to healthy controls, fMRI reveals activation of left cerebellar lobules III and IX to biological motion, implying a midline shift of cerebellar activation. Psychophysiological interaction (PPI) analysis shows that, as in normalcy, the left cerebellum interacts with a region in the right STS, which is located more anteriorly than in healthy participants. The psychophysical findings indicate a remarkable potential for recovery of biological motion perception after removal of a left cerebellar tumor. Brain imaging data reveal topographical cerebro-cerebellar network reorganization as underlying compensatory mechanism, and suggest that cerebellar lesions may induce plasticity in the cerebral cortex.

41.12, *8:30 am*

Perception with an eye for motion: seeing the world through a 3D motion filter

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We have previously demonstrated that human observers are able to identify scene-relative object movement against the complex pattern of retinal motion that arises during self-movement ("flow parsing", Rushton & Warren, 2005, Current Biology). Here we examined the time-course of the parsing process. We placed a small probe to one side of a central fixation point and a hemi-field of twinkling dots to the other. On each trial, at predetermined times, the dots would move radially inwards or outwards, and the probe would briefly (35ms) appear and move, at one of three speeds, towards or away from fixation. Observers indicated whether they perceived the probe as moving inwards or outwards. From their responses we were able to estimate the magnitude (or presence) of the flow parsing effect: any discrepancy between the physical and perceived motion could be attributed to the parsing process. In a first experiment we manipulated the duration of the flow and established that parsing occurs with as little as 17ms of flow. In a second experiment we manipulated the asynchrony between the onset of the flow and the probe motion. We found that the parsing effect was maximal when the two appeared simultaneously. In a last experiment we assessed how rapidly the flow parsing process occurs. We first established how quickly (reaction times) observers can detect inward or outward movement of the probe. We then examined the impact of the movement of dots in the hemifield on the detection time. We found that by moving the dots in the opposite radial direction to the probe it was possible to reduce reaction times. This indicates a remarkable, very low-level, direct and essentially instantaneous, interaction between global (3D) and object motion processing. We might summarise the results as indicating that we perceive the world through a 3D motion filter.

Acknowledgement: Wellcome Trust

41.13, *8:45 am*

Reliable non-veridical perception of brief moving stimuli

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Observers are sensitive to many sources of motion information. Studies have differentiated between the processing of first-order (luminance-defined) motion and motion defined by second-order cues such as contrast, texture, or disparity. Additionally, observers can use attention to track spatial displacement of features, reconstructing motion direction from sequential shifts in position. These disparate sources of motion information have different spatial and temporal characteristics, and consequently are not equally reliable across stimulus conditions. Typically, first-order motion information dominates perception at short durations. However, we previously demonstrated that increasing the size of high-contrast moving stimuli preferentially suppresses first-order motion information, while sparing second-order motion information (Glasser & Tadin, 2011, JOV). Here, we hypothesized that observers would make systematic errors in the discrimination of large, brief moving stimuli that may reflect changes in the strength and validity of different motion cues. Using a custom 360Hz display system, we found that, for brief stimuli (Gaussian temporal envelope, σ <15 ms), observers consistently perceive the motion direction of large, high-contrast gratings opposite to their physical movement (i.e., leftward motion is reliably perceived as rightward, and vice versa). If either stimulus size or contrast is decreased, observers' discriminations again became veridical. These manipulations (increased size and contrast) are associated with stronger spatial suppression, and therefore with weakened first-order motion processing. Finally, we also show that motion reversal does not occur with non-periodic narrow-band random noise stimuli. These results suggest several, not necessarily exclusive explanations. The perceived motion reversal might arise from veridical motion information being suppressed by non-informative, or weakened, cues (cf. Baker, Meese & Georgeson, in press, i-Perception). Alternatively, in the absence of reliable first-order information, perception may rely on second-order and/or tracking mechanisms that may be more susceptible to illusory reversals or aliasing. We are currently conducting experiments to differentiate between these possible explanations.

Acknowledgement: R01 EY019295, P30 EY001319, and T32 EY007125

41.14, *9:00 am*

Perception of global trend from dynamic stimuli

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We can extract general trends as well as momentary values when we look at ongoing natural and social events. We constantly make such judgments all the way through the duration of events. To understand computational principles underlying the perceptual decision on global trends (and momentary values) of temporally varying data, we analyzed human judgments for a Gabor patch with temporally fluctuating orientation or motion direction. The stimulus was presented for 2-4 seconds, and either its orientation or motion velocity temporally fluctuated according to a Gaussian distribution with particular mean and variance. Observers were asked to judge the temporal average of orientation (right / left, not the direction of rotation) or motion direction (rightward / leftward). They were asked to respond as soon as possible after the stimulus onset in one condition, or to respond after the presentation in the other condition. In a separate experiment, the observer judged not only the temporal average, but also the momentary value of orientation or motion direction at the moment that was specified by a flash of small square. By using image classification and multiple logit analysis, we calculated the impact of feature values (orientation, phase, and velocity) at each temporal frame upon the observ-

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ers' responses. The results revealed five basic characteristics of human decisions on dynamic events. (1) Primacy-recency effects: judgments on global trend strongly depend on local information at around stimulus onset, stimulus offset, and the observer's responses. (2) Low-pass property: features at rapid change are ignored for calculating global trends. (3) Robust averaging: outliers are ignored. (4) Temporal crowding: judgments on local values are inaccurate and based on information over approximately ±150ms. (5) Local-global interactions (leak effect): judgments on temporal average are influenced by the value at the cued moment.

41.15, *9:15 am*

No dedicated second-order motion system in the periphery Rémy Allard[1](remy.allard@umontreal.ca), Jocelyn Faubert[1]; [1]Visual Psychophysics and Perception Laboratory, School of Optometry, Université de Montréal

The existence of a second-order motion system distinct from both the first-order and the feature tracking motion systems remains controversial. We recently suggested that the first-order motion system could process contrast-defined motion due to non-uniform preprocessing nonlinearities introducing different distortion products for different first-order motion units (Allard & Faubert, 2008; 2012). At temporal frequencies too high for features to be tracked, we found no texture (i.e. contrast-modulation) contribution to motion when non-uniform preprocessing nonlinearities were neutralized by adding a high-contrast luminance modulation drifting with the contrast modulation. The texture contribution to motion was measured by superimposing another luminance modulation drifting in the opposite direction and asking observers to adjust its contrast until they perceived no net motion. The texture contribution to motion was defined as the contrast difference between the two luminance modulations when no net motion was perceived. The goal of the present study was to investigate if we have a dedicated second-order motion system operating at low temporal frequencies (1.875 Hz). To neutralize the feature tracking motion system, we presented the motion (radial modulations rotating either clockwise or counterclockwise) in the near periphery (annulus spatial window between 5 and 9 degrees of eccentricity) and varied the spatial frequency of the modulations (1 to 64 cycles per circumference). In the periphery, where attention resolution is low, it should be impossible to attentively track bars if they are too close to one another (i.e. crowding) to be individually selected. Results showed no texture contribution to motion when both the non-uniform nonlinearities were neutralized and the bars of the gratings were too close to one another for attention to individually select and track them (more than 16 cycles per circumference, which corresponds to about 0.38 cpd). We conclude that there is no dedicated second-order motion system operating in the periphery.

Acknowledgement: This research was supported by NSERC discovery fund and by the NSERC-Essilor industrial research chair awarded to Jocelyn Faubert.

41.16, *9:30 am*

The perceived motion of three varieties of moving barberpole stimuli George Sperling[1](sperling@uci.edu), Peng Sun[1], Charles Chubb[1]; [1]Department of Cognitive Sciences, University of California, Irvine

In foveal view, the moving barberpole stimulus looks like several barber poles drifting horizontally. It is produced by a diagonal sinusoidal carrier grating with bars drifting up to the right, windowed by a raised, vertical, horizontally-drifting sinusoid. Unlike stationary barber poles, the rigid-motion direction of this stimulus is diagonal, not vertical. Previously, Chubb, Sun & Sperling (2012), demonstrated that pure vertical motion--the barber pole illusion (BPI)--was observed in peripheral but not foveal viewing. Hidden formatting deleted. Delete this text! yes"> Experiments: Peripheral viewing. (1) Decreasing carrier temporal frequency below 10 Hz (enabling higher-order motion systems to participate) caused the perceived motion to deviate from BPI. As carrier speed approached zero, the overall motion (all that could be perceived peripherally) was perceived in the rigid (diagonal) direction . Thus, peripheral BPI in this stimulus requires first-order motion. (2) Flipping the carrier contrast between barber poles removed the global carrier fundamental component but had no effect on the perceived BPI. This shows that the first-order motion component on which BPI depends is local (within a pole) rather than global. (3) Filling the low-contrast regions between barber poles with flickering gratings (lateral masking) failed to abolish the peripheral BPI. In the fovea, the unmasked moving-barber-pole stimulus appears to move in complex patterns. Remarkably, the between-pole masking produced the simple BPI in the fovea. The between-pole masking removed the contrast modulation needed by higher-order motion systems to detect the horizontal pole movement and thereby masking equalized fovea and periphery. Conclusions. The vertical BPI in the moving barberpole stimulus cannot be explained by any Fourier motion components nor any combination thereof, nor by higher-order motion or feature-tracking. Consistent with Chubb et al (2012), the BPI in the moving barberpole stimulus is produced by a higher-order streaming process fed by first-order motion.

Acknowledgement: NSF Award BCS-0843897

Attention: Features and objects

Monday, May 13, 8:15 - 9:45 am

Talk Session, Royal Ballroom 4-5

Moderator: Stefanie Becker

41.21, *8:15 am*

Effects of image content and content-selective attention on the form-evoked BOLD response in the ventral visual areas: a linear sum-of-components model Pinglei Bao[1](pbao@usc.edu), Bosco S. Tjan[1,2]; [1]Neuroscience Graduate Program, University of Southern California, [2]Department of Psychology, University of Southern California

The neural activity along the ventral vision pathway is modulated by attention and the category of the attended image content. Unattended content also affects the neural activity. While the interaction between attention and image content can be convoluted, we found an exceedingly simple relationship between the fMRI BOLD response and the content of a complex image. We conducted three complementary experiments in which observers had to compare either the face or scene component of a pair of briefly, successively presented images, each an amalgamation of face, scene and random noise pattern. We found that the BOLD response to each non-noise image component (face or scene, attended or unattended) is linear in the "signal proportion" of the component, defined as the ratio of the contrast energy of the component to the contrast energy of the entire image. For a cortical area along the ventral visual pathway, the slope of this linear function depends on whether the component is attended and the category specificity of the cortical area. The net BOLD response of a cortical area is a simple sum of the responses to all of the non-noise components. We validated this linear sum-of-components model by showing that a model fitted to the data from any two of the three experiments can accurately predict the empirical results of the third. The model is compatible with the biased competition theory of attention and embeds a common form of divisive normalization (the Naka–Rushton expression with an exponent of 2).

Acknowledgement: US National Institutes of Health grant R01-EY017707

41.22, *8:30 am*

Object-based selection is not mandatory: Perceptual load reduces the attentional boost of task-irrelevant features in the human visual cortex. Jocelyn Sy[1](Jocelyn.l.sy@vanderbilt.edu), Janneke Jehee[2], Frank Tong[1]; [1]Department of Psychology, Vanderbilt University, [2]Donders Institute for Brain, Cognition, and Behavior, Radboud University Nijmegen

Theories of object-based selection postulate that attending to a particular feature of a visual object should obligatorily result in the selection of the whole object, including its task-irrelevant features. Some studies provide evidence to support these theories, but others have found conflicting evidence of reduced responses to unattended features, suggesting that, in some cases, attention can filter out irrelevant object properties. Here, we investigated whether variations in perceptual load might account for these disparate findings, given that conditions of high load would require considerable attentional resources, leaving little in the way of residual resources to spread to task-irrelevant features of the attended stimulus. Observers performed a contrast discrimination task on one of two laterally presented gratings while fMRI BOLD responses in early visual areas V1-V3 were measured. Spatial attention to one of two gratings was directed by a central cue, while the difficulty of the contrast judgment was manipulated to be low or high perceptual load. To test whether perceptual load influences neural responses to task-irrelevant visual features within an attended object, we measured the strength of orientation-selective responses using a signal detection-based pattern analysis. Under low perceptual load, we found greater discriminability of orientation-selective responses for spatially attended than unattended stimuli. In contrast, we observed no attentional enhancement of task-irrelevant orientation responses under high perceptual load. These results demonstrated that whole-object selection is not mandatory, but rather, the selection of irrelevant features is influenced by perceptual load. More specifically, the results are consistent with perceptual load accounts of attention that posit that attention is likely to "spill over" to irrelevant information, including irrelevant feature dimensions of an object, under low perceptual demand, whereas irrelevant information is filtered under high demand.

Acknowledgement: Vanderbilt Vision Research Center, National Eye Institute Training Grant T32EY007135 to JS and National Eye Institute grant R01 EY017082 to FT

41.23, *8:45 am*

High-Level Semantic Information Affects Attentional Allocation Within and Between Objects George Malcolm[1](glmalcolm@gwu.edu), Sarah Shomstein[1]; [1]Department of Psychology, The George Washington University

Past research strongly suggests that object representations influence attentional selection. The classic two-rectangle paradigm (Egly, Rafal & Driver, 1994) demonstrated the object based attention (OBA) effect, wherein attention is prioritized to regions within an attended object compared to regions inside a separate, equidistant object. This effect is accentuated when low-level features differ between the two objects (Shomstein & Behrmann, 2008). Although OBA research has concentrated on attentional allocation within simple shapes, our natural environment is rich in objects inherent with both low-level (e.g., color) as well as high-level (e.g., a knife) properties, and an efficient visual system would benefit from utilizing either source of information. However, the effect of high-level semantic information on OBA has yet to be elucidated. In a series of experiments, we adapted the two-rectangle paradigm to contain real-world objects and manipulated low-level feature and high-level semantic properties, independently. Low-level features were manipulated by rendering the color between objects same or different. Conversely, high-level properties were manipulated by varying the strength of the semantic relationship between the objects: high (e.g., fork-knife), low (e.g., fork-marker), or same (e.g., fork-fork). Attentional prioritization between object pairs varied with the strength of the semantic relationship, independently of low-level features. A strong semantic relationship increased prioritization within the same, attended object, while both weak and same semantic object pairs showed increased prioritization within the unattended, different object. We thus conclude that low-level feature and high-level semantic information affect object-based attentional allocation independently, and that semantic information can override low-level features when guiding attention. These findings strongly advocate the need to investigate object-based attentional guidance in real-world images, and provide further constraints on mechanisms of attentional selection.

Acknowledgement: National Science Foundation BCS-1059523

41.24, *9:00 am*

Functional activity patterns encoding the identity of anticipated objects are marked by converging shape and color decoding in early visual areas during preparatory visual attention Marc N Coutanche[1](coumarc@psych.upenn.edu), Sharon L Thompson-Schill[1]; [1]Department of Psychology, University of Pennsylvania

Theories of visual attention hypothesize that neural codes activated while people view objects can also become active when they anticipate an object's appearance, supported by prior findings of attention-driven neural activity in brain regions that process visual features. Using functional magnetic resonance imaging (fMRI) with multi-voxel pattern analyses, we have decoded object-identity, as well as the color and shape, of subjects' attentional targets after asking them to detect one of four fruits and vegetables within blocks of visual noise ending with a hidden object. Analyzing only the time-points without visual information on-screen, we find that the simultaneous emergence of feature-specific codes in early visual cortex co-occurs with decodable object-identity information later in the visual stream. We first report that a left anterior temporal region can decode object identity during preparatory attention, with neural patterns that match the activity patterns generated when subjects actually view examples of the targeted fruit or vegetable. Second, a classifier trained to differentiate time-points when people anticipate items that differ by shape can successfully distinguish a different set of attentional targets that vary in the same way using data from the lateral occipital cortex. In contrast, V4 activity patterns can generalize to new attentional targets varying by both shape and color. Third, blocks that were characterized by converging successful decoding of shape (e.g., spherical) and color (e.g., orange) in the lateral occipital and V4 regions were accompanied by successful decoding of object identity (e.g., tangerine) in the left anterior temporal lobe during visual attention to that target. Finally, the temporal lobe patterns of subjects showing strong relationships between simultaneous feature-decoding and successful object identity decoding, more closely resembled patterns generated from passively viewing the targets. Our findings support the idea that top-down processes activate various specialized representations in the visual hierarchy during preparatory attention.

Acknowledgement: NIH

41.25, *9:15 am*

Everything is relative: Contingent capture depends on feature relationships. Stefanie I. Becker[1](s.becker@psy.uq.edu.au), Charles L. Folk[2], Roger W. Remington[1]; [1]School of Psychology, The University of Queensland, Brisbane, Australia, [2]Department of Psychology, Villanova University

How do we select relevant information from cluttered visual environments? The prevalent view is that the intention to search for a particular feature enhances the attentional gain for the target feature or an exaggerated target feature shifted away from the nontarget feature value distribution (optimal tuning; e.g., Navalpakkam & Itti, 2007). By contrast, according to a new relational account, attention is not tuned to specific feature values, but only to the contextual properties that an item has relative to the features of the surrounding context (Becker, 2010). In the present study, we used a variant of the spatial cueing paradigm to test the relational account against current feature-based theories. Observers had to search for a target with a particular color (e.g., orange) among 3 nontargets of a different color (e.g., yellow-orange). To test whether attention would be tuned to the target color (e.g., orange), the exaggerated target color (e.g., red) or the target-nontarget relationship (e.g., redder), we presented an irrelevant distractor with a unique color prior to the target display (singleton cue), that was embedded in a context of three other cues (cue context). The results showed that capture by the singleton cue depended only on whether the cue's relative color to the cue context matched or mismatched the target-nontarget relationship, and was entirely independent on whether it had the same or a different color as the target. Specifically, singleton cues with the target color failed to capture attention when the cue-cue context relationship mismatched the target-nontarget relationship. Singleton cues whose cue-context relationship matched the target-nontarget relationship captured even when the singleton cue had the nontarget color. These results invalidate current feature-based theories of attention and provide strong support for the relational account, that attention is usually biased towards the relative properties of the target.

Acknowledgement: ARC Discovery Grant to Stefanie I. Becker (DP110100588)

41.26, *9:30 am*

Attending to what and where: Background connectivity integrates category-based and spatial attention Naseem Al-Aidroos[1](naseem@uoguelph.ca), Alexa Tompary[2], Nicholas B. Turk-Browne[3]; [1]Department of Psychology, University of Guelph, [2]Department of Psychology, New York University, [3]Department of Psychology, Princeton University

We recently demonstrated that attention to visual categories is associated with increased coupling between low-level visual areas selective for basic features and high-level areas selective for the attended category (Al-Aidroos, Said, & Turk-Browne, 2012, PNAS). For example, retinotopic area V4 coupled more with the fusiform face area (FFA) under face attention and the parahippocampal place area (PPA) under scene attention. Here, we investigate how spatial attention affects coupling, and how such modulation might interact with category-based coupling. Conventional neural measures often suggest that spatial and feature-based/category-based attention operate independently, so integrated changes in coupling may help to explain how people coordinate multiple attentional goals. Participants completed a combined space/category attention task in which they fixated centrally while viewing face images on one side of fixation and scene images on the other. Thus, across fMRI runs, they attended to left faces, right faces, left scenes, or right scenes. All images appeared in the upper visual field, projecting to the perceptually-dominant ventral stream. We used background connectivity to assess coupling: Stimulus-evoked responses and global noise were removed from the data, allowing analysis of the noise correlations between areas for the four attentional states. We found three main results. First, when attending to upper visual field images, FFA/PPA connectivity was enhanced for ventral V1-V3, but suppressed for dorsal V1-V3. Second, attending to images in one hemifield enhanced FFA/PPA connectivity with contralateral, more than ipsilateral, visual areas. These spatial attention results generalize our previous category findings, suggesting that modulation of coupling is a fundamental mechanism for top-down attention. Third, enhanced connectivity with task-relevant category areas was limited to task-relevant

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spatial areas (e.g., left-face attention enhanced FFA but not PPA connectivity, and only with right but not left V4). In this way, changes in coupling can support the integration of two distinct types of top-down attention.
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Perception and action: Mechanisms and models

Monday, May 13, 10:45 - 12:30 pm

Talk Session, Royal Ballroom 1-3

Moderator: Gabriel Diaz

42.11, *10:45 am*

Unconscious mimicry limits success in a competitive visual reaching task

Ken Nakayama[1](ken@wjh.harvard.edu), Maryam Vaziri Pashkam[1], Marnix Naber[1,2]; [1]Department of Psychology, Harvard University, [2]Department of Psychology, University of Leiden

Individual skills such as endurance and speed determine success in competitive game-play and sports. It is, however, less obvious whether players can mutually modulate each other's skills in such circumstances. Here we demonstrate that players are highly susceptible to implicitly mimic their opponent's behavior. In our experiments, pairs of players stood on opposite sides of a touchscreen table on which many targets were shown for short durations. Players could earn money by reaching these targets before their opponent. They used a small stick to hit targets and visual feedback was given to indicate the winner. A magnetic tracking sensor was attached to the stick such that hit reaction times and three dimensional movements could be measured at a rate of 120Hz. Results showed that, despite the strongly competitive nature of the game, opponents mirrored each other's movements and reaction times. In a second experiment, a new group of players played against a confederate. The confederate was instructed to modulate his performance by playing either slow or fast in consecutive blocks. Data showed that players mimicked the confederates performance and movements across blocks while they were unaware of this behavior. Mimicry was thus maladaptive and decreased financial reward for the players in cases where the confederate performed worse. In sum, it seems that people cannot suppress the implicit tendency to mimic the movements and reaction times of others, even under competitive circumstances. Mimicry is seemingly so strong and automatic that it can determine success in competitive game-play.

42.12, *11:00 am*

Learning category contingent speed priors for object interception

David Knill[1, 2](knill@cvs.rochester.edu), Oh-Sang Kwon[1,2]; [1]Center for Visual Science, University of Rochester, [2]Dept. of Brain and Cognitive Sciences, University of Rochester

Introduction: When planning movements to intercept a moving target, humans use adaptive statistical models of speed distributions and temporal correlations to estimate target velocity. The current experiment tested whether and how subjects learn category-contingent statistical models of object speed when presented with targets with mixed distributions. Methods: Subjects viewed target objects that moved briefly (200 – 300 msec.) in a virtual display before disappearing behind a variable-length occluder. Their task was to hit an "impact-zone" drawn on the occluder when the object passed behind it. In a first ("hard") experiment, two types of targets were randomly interleaved from trial-to-trial - red-square targets had speeds drawn from a distribution with a small variance while green-circular targets had speeds drawn from a distribution with the same mean but with a large variance (or vice-versa for half of the subjects). In a second ("easy") experiment, the means of the distributions also differed significantly. Results: In both experiments, subjects showed a significantly larger bias to the mean for the low-variance category than the high, had a marginally significant greater bias to the previous stimulus when it was from the same category than when it was from a different category and adapted their timing behavior to the feedback on the previous trial significantly more when the previous stimulus was from the same category. Despite these differences, their behavior on a trial was still significantly affected by both the speed of the target and the hitting error on the previous trial even when it was from a different category. Conclusions: Subjects partially learn separate priors for different categories, but retain temporal biasing affects from stimuli across categories. This suggests a model in which observers use categorization cues probabilistically, rather than as absolute cues to category membership for purposes of imposing prior models on speed estimates.
Acknowledgement: NIH -R01EY017939

42.13, *11:15 am*

Rational delusions: changing subjects' beliefs about the dynamics of probabilistic environments determines sequential effects in reaction times

Friederike Schuur[1](f.schuur@nyu.edu), Brian Tam[1], Laurence T. Maloney[1]; [1]Psychology, New York University

In perception, action, and decision-making, participants exhibit automatic, apparently suboptimal sequential effects (SQE): they respond more rapidly to a stimulus if it reinforces local patterns in stimulus history. We investigate whether SQE are driven by mechanisms critical for adapting to a changing (i.e. dynamic) world. Mere presence of SQE suggests an emphasis on the recent over the distant past in predicting upcoming events, a rational response in dynamic environments. Previously reported biases in SQE toward repetition versus alternation may be due to prior beliefs about what environments look like after change. Subjects completed a modified version of "Whack-a-Mole". Sesame Street's Elmo popped up either to the right or left of fixation. Participants were instructed to press a spatially congruent button as fast as possible but not at the expense of accuracy. In Session 1 and 3, repetitions and alternations in Elmo's location were equally likely (p(repetition) = 0.5). In Session 2, p(repetition) was repeatedly sampled from a Beta-distribution with B(6,12) for "alternation-training" and B(12,6) for "repetition-training". Resampling occurred at p(resample) = 0.18 and was signaled to the subject to allow them to learn the environment's "change-rate". Participants' reaction times (RT) showed SQE in all sessions. Prior to training, participants were biased towards alternations. After training, repetition-trained participants were biased towards repetitions while alternation-trained participants remained biased towards alternations. Modeling shows that this training-induced bias in SQE can only be due to prior beliefs about the probability to observe a repetition versus alternation. Importantly, participants' belief in a dynamic environment was sufficient to produce these biased SQE. This belief may act as a self-fulfilling prophecy: if probability estimates are derived with an emphasis on the recent past, then stable environments seem dynamic. Pervasive SQE on perceptual, motor, and decision tasks should surprise no one.
Acknowledgement: National Institutes of Health EY019889

42.14, *11:30 am*

Physical prediction biases are faithful physics plus visual uncertainty

Kevin Smith[1](k2smith@ucsd.edu), Edward Vul[1]; [1]Department of Psychology, University of California, San Diego

To plan actions in the world, people must account for how it will change over time: for instance, catching a ball requires predicting its trajectory. People do this easily and flexibly, reflecting an underlying knowledge of physics, but they show task specific biases in applications of these physical principles. We propose that people use one physical model across tasks, but different sources of uncertainty interact with task demands to produce such task-specific biases. Each participant predicted where a pendulum bob would fall after the string had been cut in two qualitatively different tasks. In the 'catching' task, the computer chose when to cut the string, and we measured where participants moved a bucket horizontally to catch it. In the 'cutting' task, we measured when participants cut the string to make the bob fall into a bucket placed by the computer. All participants performed the same trials in each task, and showed high inter-subject reliability (split-half correlations – catching: r=0.993, cutting: r=0.998). Trials were matched across tasks such that where the ball landed in a 'catching' task was the bucket position in the matched 'cutting' trial. Thus, these tasks employ the same physical system, but are differentially sensitive to uncertainty in the location and speed of the bob, and elicited distinct biases: in the 'catching' task, participants placed the bucket closer to the center than the true landing position, while in the 'cutting' task, participants tended to overshoot the bucket. Aggregate participant responses in both tasks were well predicted by a physical model (catching: r=0.994, cutting: r=0.992) that differed across task only in which sources of visual uncertainty were relevant. These results suggest that people use a single model of the physical world, but that biases can occur due to the interactions of perceptual uncertainty and task demands.

42.15, *11:45 am*

Prediction compensates for occlusion of a bounced ball

Gabriel Diaz[1](gdiaz@mail.cps.utexas.edu), Joseph Cooper[2], Mary Hayhoe[1]; [1]The Center for Perceptual Systems at UT Austin, [2]The Department of Computer Science at UT Austin

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Intercepting a rapidly moving target is complicated by the presence of sensory and motor delays that prevent the immediate use of new visual information. Although humans can compensate for these delays by predicting the future state of the visual environment, little is known about the underlying mechanisms. Previously, we investigated prediction in a virtual racquetball task in which the ball bounced once during its approach to the subject. Subjects were found to make predictive saccades to a location that the ball would arrive after the bounce. This location was fixated until the ball's arrival, and fixation was immediately followed with a pursuit movement. Although we manipulated post-bounce ball speed by changing ball elasticity and pre-bounce speed, subjects adjusted their predictive fixations to maintain an average duration of 170 ms between the bounce and the ball's arrival at the fixation, in all conditions. This constant-time strategy was accomplished by raising fixation height for balls that moved faster after the bounce. In this study, we test competing hypotheses for the constant-time strategy, for example, that this strategy allowed sufficient time to program the post-bounce pursuit. Pre-bounce speed varied on each trial (3 bounce-speeds x 30 repetitions = 90 trials per block). In a second block, the ball was always invisible for 100ms following the bounce. The data revealed that occlusion had only a minimal effect on pursuit performance. Fixation height was unaffected, and the predictive saccade was delayed by ~30 ms, allowing for a slightly extended viewing of the pre-bounce trajectory. Thus, one possibility is that subjects compensated for occlusion by placing greater emphasis on prediction using pre-bounce visual information. This interpretation is also consistent with the observation that, on some occlusion trials, pursuit was initiated in prediction of the ball's reappearance.

Acknowledgement: Supported by NIH grant EY05729

42.16, *12:00 pm*

Quantifying changes in the kinesthetic percept under a 3D perspective visual illusion Jillian Nguyen[1,2,5](jinguyen@eden.rutgers.edu), Robert Isenhower[3,5], Polina Yanovich[2,5,6], Jay Ravaliya[2,4], Thomas Papathomas[1,2,4], Elizabeth Torres[3,5,6]; [1]Department of Neuroscience & Cell Biology, Rutgers University & UMDNJ, [2]Laboratory of Vision Research, Center for Cognitive Science, Rutgers University, [3]Department of Psychology, Rutgers University, [4]Department of Biomedical Engineering, Rutgers University, [5]Sensory-Motor Integration Lab, Rutgers University, [6]Department of Computer Science, Rutgers University

Objective: To explore how reaches toward a target embedded in 3D scenes are affected by top-down and bottom-up signals when participants perform the task at their comfort pace or at instructed slow/fast speeds. Methods: Two 3D stimuli: (1) A proper ("forced") perspective, where the perspective-painted cues are congruent with bottom-up signals (binocular disparity, motion parallax, etc.). (2) A reverse-perspective, where the painted cues compete with bottom-up signals, thus eliciting bistable percepts of (a) veridical depth or (b) illusory reverse-depth; the illusion affects perceived 3D surfaces orientations drastically. Under binocular viewing conditions, subjects viewed the stimuli and grabbed at planar disk targets at their own set pace or at fast or slow speeds as instructed, while we recorded their full motor response from initiation of movement towards the target to the hand retraction to resting position. Results: For reaches performed under comfort speeds, the curvature and length of hand-path trajectories were significantly affected by the illusion. Reaches performed under the veridical percept differed markedly from reaches under the illusory and the proper percepts. Trajectories under illusory and proper percepts were strikingly similar. Additionally, this held true both in the goal-directed movement towards the target and in the spontaneous hand retraction. When speed instructions were added, reaches under the illusory percept did not statistically differ from either the veridical percept or the proper percept. Conclusions: Overall we find compelling evidence that top-down visual processes affect both our visual and our kinesthetic percepts. The interactions between the illusory percept and the commanded speed strongly manifested in the retraction movements, which ceased to be spontaneous and turned more deliberate, despite lack of instructions regarding their performance. We discuss our results in the context of deliberate and automatic mental processes that take place during motor decisions and program selection in the face of sensory-motor noise.

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42.17, *12:15 pm*

'Top-down' effects where none should be found: The El Greco fallacy in perception research Chaz Firestone[1](chaz.firestone@yale.edu), Brian Scholl[1]; [1]Department of Psychology, Yale University

A tidal wave of recent research purports to have discovered that higher-level states such as moods, action-capabilities, and categorical knowledge can literally and directly affect what we see. Are these truly effects on perception, or might some instead reflect influences on judgment, memory, or response bias? Here, we exploit an infamous art-historical reasoning error (the so-called "El Greco fallacy") to demonstrate in five experiments that multiple alleged top-down effects (ranging from effects of morality on lightness perception to effects of action capabilities on spatial perception) cannot truly be effects on perception. We do so by actively replicating these very effects, but in previously untested circumstances where their motivating theories demand their absence. We first replicated a finding that holding a wide rod across one's body decreases width estimates of a potentially passable aperture, as measured by subjects' adjustments of a tape. However, we also observed the same narrowing effect when the 'matching' instrument was itself an aperture (instead of a tape). If rod-holding truly makes apertures look narrower, then this second experiment should have 'failed', because both apertures should have looked narrower, with the distortions cancelling out. A second series of experiments replicated a finding that recalling unethical deeds makes stimuli look darker, as measured by ratings on a 7-point number scale. However, we also observed the same darkening effect when the scale itself consisted of 7 grayscale patches (which should themselves have looked darker, too!). In each of these cases, the alleged effect is real but cannot be perceptual — since if it were, then the instrument used to measure it would have been similarly distorted, and the distortions would have cancelled out. We suggest that this new research strategy is widely applicable, and has broad implications for debates over the (dis)continuity of perception and cognition.

Object recognition: Higher order

Monday, May 13, 10:45 - 12:30 pm

Talk Session, Royal Ballroom 4-5

Moderator: Maryam Vaziri Pashkam

42.21, *10:45 am*

Object interaction space represented in scene-selective regions

Wilma Bainbridge[1](wilma@mit.edu), Aude Oliva[2]; [1]Department of Brain and Cognitive Sciences, MIT, [2]Computer Science and Artificial Intelligence Laboratory, MIT

Previous work has shown that different cortical regions are sensitive to objects of differing real-world sizes (Konkle & Oliva, 2012; Mullally & Maguire, 2011; Bainbridge et al, 2012). Whereas a region in the occipito-temporal sulcus (OTS) shows small object selectivity, scene-selective regions (parahippocampal place area, PPA; retrosplenial cortex, RSC; and occipital place area, OPA) show systematically more activity for objects that are large in the world than smaller objects. What is the nature of this scene-like representation of objects? Here, we study an affordance-based object property: "interaction space". Interaction space is the area around objects that users traverse when interacting with the object. This interaction may include calculations of grasping points and surface area of contact, and is not necessarily conjoined with size. To fully deconvolve object interaction from physical size, we conducted a 2 x 2 factor design fMRI study with four conditions: 1) small one-handed objects (i.e., hairbrush), 2) large one-handed objects (i.e., umbrella), 3) small two-handed objects (i.e., hamburger), and 4) large two-handed objects (i.e., guitar). Stimuli were matched for ground truth size (based on physical sizes and weights), subjective size from an online survey, color, luminance, spectral energy, and retinal size. Results from a 2-factor ANOVA on beta values in functionally-defined ROIs show PPA, OPA, and RSC are sensitive to interaction space regardless of size, while PPA, OPA, and OTS are also sensitive to size regardless of interaction space. Importantly, effect sizes for interaction space in the PPA, OPA, and RSC were greater than those for object size, while the reverse was true for the OTS. These results show that interaction space is a perceptual object property that is represented in scene-selective regions, and suggest an overlapping interaction-based representation of objects and scenes in the brain.

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42.22, *11:00 am*

Inferring "hidden" parts by learning hierarchical representations of objects Hongjing Lu[1,2](hongjing@psych.ucla.edu), Alan Lee[1]; [1]Psychology Dept, UCLA, [2]Statistics Dept, UCLA

Although hierarchical representation is known to foster the robustness of the object recognition system, there is no direct psychophysical evidence showing how humans acquire hierarchical representations of objects via statistical learning. We hypothesize that if the visual system learns objects in terms of hierarchical dictionaries of parts, humans will be able to infer "hidden" parts, which have not been perceived directly, as the complement of parts that have been observed. 12 elementary shapes were randomly combined to make objects. The inventory included objects composed of four shapes (termed quadruples) and objects composed of two shapes (termed pairs). One of the object quadruples was chosen to be the target, and a pair of shapes embedded within it was chosen to be the trained embedded part (TEP). During training, observers first learned object parts in a detection task, and then were presented with 104 distinct training images in which multiple objects were presented without clear segmentation. Object familiarity was measured in the subsequent test trials. For the non-target quadruple objects, observers failed to recognize their parts (accuracy of 0.53), replicating a previous finding reported by Fiser and Aslin (2005). However, for the target quadruple object, after learning the TEP, observers were able to recognize the complementary part with accuracy of 0.70, even though this complementary part had never been displayed alone. A second experiment further revealed that passive viewing of TEPs was not sufficient to establish the part-based representation that enables the inference of hidden parts. In summary, these two studies suggest that the key to the human ability to form hierarchical representations is the reuse of previously learned knowledge about object parts, enabling a compositional mechanism for forming object representations.

42.23, *11:15 am*

Complex object representations in the medial temporal lobe: Feature conjunctions and view invariance Jonathan Erez[1](jonathan.erez@utoronto.ca), Rhodri Cusack[2,3], Will Kendall[1], Morgan Barense[1,4]; [1]Department of Psychology, University of Toronto, Toronto, ON, Canada, [2]Department of Psychology, University of Western Ontario, London, ON, Canada, [3]The Brain and Mind Institute, London, ON, Canada, [4]Rotman Research Institute, Toronto, ON, Canada

The medial temporal lobe (MTL) is known to be vital for memory function. However, recent studies have shown that a specific set of brain structures within the MTL are also important for perception. For example, studies of amnesic patients with damage to MTL structures indicated that these patients performed poorly on perceptual tasks, specifically, when discriminating between items that shared overlapping features. It was suggested that one MTL structure in particular, the perirhinal cortex (PRC), should be considered part of the representational hierarchy in the ventral visual stream (VVS) and is responsible for representing the complex conjunction of features that comprise objects, perhaps at a view-invariant level. In this study we investigated how the different features comprising complex objects are represented throughout the VVS up to and including the MTL, and at what stage the representations become view-invariant. To address these questions, we used multi-voxel pattern analysis (MVPA) of fMRI data, a technique that has gained prominence for its ability to probe the underlying neural representations of visual information. Participants completed a one-back task involving novel objects that were comprised of either one (e.g., A, B, or C), two (e.g., AB, AC, BC), or three features (e.g., ABC) and were presented from one of two possible viewpoints. This allowed us to examine the degree to which neural representation of a pair of objects depended only on the sum of their parts (i.e., A+BC=AB+C), or whether the specific feature conjunctions within objects were encoded. A searchlight analysis using this method indicated that anterior regions of the VVS, including the PRC, coded the complex conjunctions of features comprising the objects, over and above the individual features themselves. Moreover, we found evidence to suggest that the conjunctive representations in PRC were view-invariant.

42.24, *11:30 am*

The representation of face identity in human parietal cortex Su Keun Jeong[1](skjeong@fas.harvard.edu), Yaoda Xu[1]; [1]Department of Psychology, Harvard University

In human fMRI studies, response amplitude of the superior intra-parietal sulcus (IPS) has been shown to track the encoding and maintenance of task relevant visual information, such as color, shape, and orientation. Consistent with this finding, we recently showed that, depending on the task demand, shape, location, or the conjunction of the two could be decoded from fMRI response patterns in this brain region. Here we investigated whether representations formed in superior IPS are limited to visual sensory information, or whether they can be extended to abstract visual information, such as viewpoint-invariant face identities. To address this question and to reduce the contribution of low-level visual features, we used face images of Leonardo Dicaprio and Matt Damon, two well-known actors matched in overall appearance. To further encourage the formation of viewpoint-invariant face identity representations, we varied viewpoint, hairstyle and facial expression of the face images and constructed two image sets for each actor. Observers viewed each image set multiple times and detected the occasional presence of an oddball face drawn from one of eight other male actors (oddball face responses were removed from subsequent analysis). In superior IPS, we found significantly higher correlations of fMRI response patterns between two sets of faces belonging to the same than different actors. This effect was not caused by the encoding of the actors' names, as the effect went away when we repeated the task but only showed the actors' names. This effect was also absent in the fusiform face area, the lateral occipital and the inferior IPS regions. Task relevant visual information can therefore be robustly represented in superior IPS even for abstract visual information such as face identity. This capability likely places the superior IPS as a key neural mechanism mediating the moment-to-moment visual information processing in the human brain.

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42.25, *11:45 am*

The role of the orbitofrontal cortex in visual prediction Olivia S. Cheung[1](olivia@nmr.mgh.harvard.edu), Moshe Bar[1,2]; [1]Martinos Center, Massachusetts General Hospital, Harvard Medical School, [2]Gonda Center for Multidisciplinary Brain Research, Bar Ilan University, Israel

Efficient object recognition is facilitated by integration of top-down and bottom-up processes. One proposed top-down mechanism is that coarse global shapes, conveyed by low spatial frequencies (LSF), are projected rapidly from early visual areas to the orbitofrontal cortex (OFC) to facilitate subsequent processing (Bar et al., 2006). To understand the nature of object representations in the OFC, we examined how this region may utilize visual and semantic object information to generate visual predictions. We hypothesized that LSF are useful for generating possible interpretations to facilitate recognition of exemplars that share similar global shapes (e.g., collie/beagle), and less so for exemplars that share dissimilar global shapes (e.g., collie/chihuahua). In an fMRI repetition-priming paradigm, we manipulated the spatial frequency content of the primes, and the visual-semantic relations between the primes and targets. The primes could be unfiltered, or contained either LSF or high spatial frequencies (HSF). The primes and targets could be identical or different objects, or visually similar or dissimilar exemplars from the same category. Participants (N=19) judged if each unfiltered target was a real-world or nonsense object. Behavioral priming, as revealed by faster RT for identical than different objects, was observed with unfiltered and LSF, but not HSF, primes. The priming effect was also stronger for similar than dissimilar exemplars. This pattern of priming results was reflected in the activity in the ventral visual stream. Critically, the LSF-driven facilitation also revealed differential activations among the prime-target relations in the object-sensitive bilateral medial OFC (defined functionally in a separate one-back task). Specifically, significantly stronger activations were observed for similar than dissimilar exemplars within a category. These results add important evidence that the OFC generates possible interpretations for visual input based on LSF, and that similar global shapes effectively engage this region for top-down facilitation in object recognition.

Acknowledgement: This work was supported by NEI-NIH grant 1R01EY019477-01, NSF grant BCS-0842947, and DARPA grant N10AP20036.

42.26, *12:00 pm*

The similarity structure of distributed neural responses reveals abstract and modality-specific representations of letters David Rothlein[1](david.rothlein@gmail.com), Brenda Rapp[2]; [1]Department of Cognitive Science, Johns Hopkins University, [2]Department of Cognitive Science, Johns Hopkins University

Most cognitive theories of visual letter processing posit modality-specific representations of letter shapes, spoken letter names, and motor plans, and also abstract, amodal letter representations that unify the various modality-specific formats. Importantly, abstract letter representations encode identity in a case-invariant manner such that markedly different letter-forms can share the same abstract letter representation (e.g. r – R). However, fundamental questions remain regarding the very existence of abstract letter representations, the neuro-topography of the different types of letter representations, and the degree of cortical selectivity for orthographic information. We use Multivariate Pattern Analysis-Representational Similarity Analysis (MVPA-RSA) specifically applying searchlight methods to directly test quantitative models of the similarity/dissimilarity structure of distributed neural representations of letters. These analyses identify substrates selectively tuned to both modality-specific (visual, phonological and motoric) representations of letters, as well as a left hemisphere occipital-temporal region within the ventral visual stream selectively tuned to abstract letter representations. We also find that these different formats of letter representation are closely integrated with neural networks used for word reading. The approaches applied address various shortcomings of previous studies that have investigated these questions and the findings serve to advance our understanding of the format of the letter representations found within sub-regions of the large-scale networks used in reading and spelling. Furthermore, the evidence of abstract letter representation provides a clear example of ventral stream encoding of object identity information that is invariant to fundamental differences in visual form.

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42.27, *12:15 pm*

The contribution of human parietal cortex to conceptual categorization Maryam Vaziri Pashkam[1](mvaziri.p@gmail.com), Yaoda Xu[1]; [1]Vision Sciences Laboratory, Department of psychology, Harvard University

Categorizing objects based on their conceptual properties is one of the key functions of human cognition. Previous monkey physiological studies have indicated the direct involvement of the primate parietal cortex in visual object categorization. Using fMRI, here we address whether sub-regions of human posterior parietal cortex contribute to conceptual categorization of objects. On a given trial, we show observers an image depicting a bike, a sneaker, a hanger or a couch (20 different exemplars are used for each object class) and ask them to perform two orthogonal conceptual categorization tasks. In the indoor-outdoor task, observers would categorize hangers and couches as being indoor and bikes and sneakers as being outdoor; and in the small-large task, they would categorize hangers and sneakers as being small and couches and bikes as being large. Because the same 4 objects are categorized into two different groups across the two tasks, we are able dissociate conceptual categorization from basic visual categorization. Furthermore, by assigning the same motor responses to two of the objects across the two tasks, we are able to dissociate categorization from motor related neural responses. We extracted fMRI response patterns from five topographic areas along the human intra parietal sulcus as well as from superior IPS (sIPS) and inferior IPS (iIPS), two parietal regions previously shown to participate in visual object individuation and identification in a short-term memory task. Using multi voxel pattern analysis and a linear support vector machine, we show that of all the parietal regions examined, only sIPS is able to distinguish between the two instances of the same object across the two tasks. In other words, sIPS represents the same object differently depending on the conceptual categorization task required. These results reveal a possible role of human parietal cortex in conceptual categorization of objects.

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Monday Morning Posters

Eye Movements: Methodology, clinical

Monday, May 13, 8:30 am - 12:30 pm

Poster Session, Royal Ballroom 6-8

43.301 Constraining Eye Movements When Redirecting Walking Trajectories in People With Parkinson's Disease

V.N.Pradeep Ambati[1](vambati@miners.utep.edu), Marlina Ponce De Leon[2], Fabricio Saucedo[2], Douglas Powell[3], Rebecca Reed-Jones[2]; [1]Interdisciplinary PhD Program, College of Health Sciences, The University of Texas at El Paso, [2]Dept. of Kinesiology,The University of Texas at El Paso, [3]School of Education, Health and Human Performance, Fairmont State University

Healthy young adults (YA) use different turning strategies when required to fixate their gaze. When free to make eye movements, a clear top-down turning sequence, where the eyes move first followed by the head, and body occurs. However, when YAs are required to fixate their gaze on a fixed target a clear bottom-up (pelvis to eyes) sequence occurs. These behaviors suggest anticipatory eye movement is critical for coordinating the body when turning. The Basal Ganglia have a central role in the control of eye movement. Therefore, examining individuals with Parkinson's Disease can provide further insight into the role of eye movements in turning control. The current study addressed the hypothesis that PD patients would not exhibit anticipatory eye movements when turning. As a result, PD patients would not exhibit top-down control strategies when turning in a Fixed Gaze or Free Gaze condition. Data analysis focused on segment kinematics (Vicon motion capture system) and horizontal eye position (Applied Science Laboratories H6 eye tracker) of seven PD patients during 90-degree walking turns in two visual conditions: Fixed Gaze and Free Gaze. Segment kinematic analysis revealed no significant difference ($p > 0.05$) in the onset of the eyes, head and trunk between the Fixed Gaze and Free Gaze conditions. In addition, intersegment timing analysis within each gaze condition revealed no significant difference ($p > 0.05$) between segments. These results indicate PD patients do not make anticipatory eye movements when turning and as a result do not use top-down turning strategies. In fact, there is no significant difference in turning strategies between Fixed and Free gaze conditions. These observations support the important role of anticipatory eye redirection for turning control. Deficits in oculomotor control could result in increased use of alternative sensory modalities for navigation when executing a turn while walking.

43.302 E-readers configured for short lines facilitates reading in those who struggle.

Matthew Schneps[1](mschneps@cfa.harvard.edu), Jenny Thomson[2], Gerhard Sonnert[1], Marc Pomplun[3], Chen Chen[1,2], Amanda Heffner-Wong[1]; [1]Laboratory for Visual Learning, Harvard-Smithsonian Center for Astrophysics, [2]Harvard Graduate School of Education, [3]University of Massachusetts, Boston

Background: People with dyslexia remark that reading on handheld e-readers is easier than traditional methods. Previous studies (Schneps, et al., 2010) suggest short linewidths used in these devices may facilitate reading in dyslexia by reducing demands on visual attention, impaired in dyslexia (Franceschini, et al., 2011). Furthermore, it was hypothesized that proximity to the hand may facilitate reading via e-readers, because response to attention is observed to be modulated by proximity to the hand (Davoli & Brockmole,2012). Experiment: Here, we report the results of an eye tracking study that compared reading on an Apple iPod Touch with reading on an iPad, in a sample of 26 high school students with dyslexia. A (2x2x2) experimental design was used: Linewidth (iPod/iPad) and use of hand (hand/no-hand) were varied as experimental conditions; and in addition, given that dyslexia is sensitive to crowding, letter spacing (normal v. wide) was varied. Reading rate, fixation statistics, saccade regression, and reading comprehension were measured. Findings: Highly significant main effects of linewidth favoring the iPod were observed in all of these variables. Furthermore, significant advantages of wide spacing (that relieve the effects of crowding) were observed, but only among those readers who were most impaired. No effect of the hand was found, and interactions were absent. Conclusions: We interpret these observations in terms of a model for reading in dyslexia. Here, we suggest that attention processes that ordinarily inhibit perception of text previously read are impaired in dyslexia ("inverse pseudo-neglect" Michel, et al.,2010). This disrupts word recognition and additionally cues readers to direct spatial attention in the wrong direction, increasing incidence of regressive saccades. We believe these effects are ameliorated in e-readers that use abbreviated linewidths, making reading using small-screen devices a potentially effective strategy for those who struggle to read.

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43.303 Instrumental activities of daily life in individuals with central visual field loss

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Introduction: Previous publications on quality of life in patients with age-related macular degeneration (AMD) report difficulties in performing vision-related daily tasks, such as reading, writing, and cooking, leading to a progressive loss of independence and decreased related functions. Patients with AMD also encounter more difficulties than do age-matched normally sighted individuals finding objects under crowded conditions. Studies on visual perception in central vision loss pathologies typically use 2D images of objects. However, images differ from the natural world in several ways, including the nature of the visual stimulus and the role of task demands. Our study assessed the ability of patients with AMD to accomplish a sequence of realistic actions using the eye movement technique. Methods: We monitored eye movements in 16 subjects with AMD and 16 age-matched normally sighted participants under two realistic active viewing conditions. Participants wore a head-mounted eye tracker, and were seated in front of a table with the objects required for accomplishing a familiar task (sandwich-making) and an unfamiliar task (model-building). The scenes contained both task-relevant and task-irrelevant objects. Temporal and spatial characteristics of gaze were compared for each group and task. Results: The results show that patients were able to perform both familiar and unfamiliar tasks, though patients were twice as slow, and less accurate than controls to copy the display model in the unfamiliar task. Patients exhibited longer gaze durations than controls on irrelevant objects in both tasks. They also looked longer at task-relevant objects and needed to manipulate the objects more in order to identify them. Although patients tended to place the task-relevant regions on a similar retinal location, there was no well-defined PRL (Preferred Retinal Locus). Conclusion: People with AMD exhibit difficulties in realistic actions but seem to establish compensatory strategies (e.g., object manipulation) to accomplish the task.

43.304 Visual exploration of objects and scenes in people with Stargardt disease and macular degeneration

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Introduction: Lesions of the macula result in loss of central vision and a dependence on low resolution peripheral vision. Most studies in people with central field loss have focused on reading which constitutes the main complaint of patients, though questionnaires of quality of life indicate impairments in daily living activities. Some studies have also reported impairments in face and in object detection or recognition tasks. Little is known about how people with central visual field loss explore realistic images. Methods: We recorded eye movements (scan paths, saccades and fixations) and naming times in patients with juvenile maculopathy (Stargardt disease, mean acuity 1/20), in patients with age related macular degeneration (AMD mean acuity 2.6/10) and in normally sighted age-matched controls (mean acuity 9.1/10). Colored photographs (32.5 X 25.8° of visual angle) of isolated objects, of natural scenes and of objects in scenes were centrally displayed for 2 sec. Eye movements were recorded with an eye tracker (SMI). Results: On average naming accuracy was higher by 30% for controls than for both AMD and Stargardt patients. This difference was equivalent for isolated objects and for objects in scenes. The proportion of fixations in regions of interest was lower in people with maculopathy than in controls. The number of saccades was larger for AMD patients than for Stargardt patients and for controls. Discussion: The results suggest that an abnormal pattern of visual exploration might contribute to deficits in object and scene recognition in both people with Stargardt disease and AMD.

43.305 **Eye Movements in Patients with Hemispatial Neglect: Why is Information Neglected?** Louise-Ann Leyland[1](ll306@soton.ac.uk), Hayward J. Godwin[1], Valerie Benson[1], Simon P. Liversedge[1]; [1]Psychology, University of Southampton, UK

It has not yet been established whether hemispatial neglect, the failure to respond to contralesional information after stroke, occurs due to an information sampling deficit or impaired processing of contralateral information during fixation. To address this, we recorded eye movements of acute (<3 months post-stroke) neglect patients (NPs), stroke controls without neglect (SCs), and older adult controls (OACs) whilst participants completed letter and clock cancellation tasks. Participants were required to search for two different target letters simultaneously amongst other distractor letters (dual-target search; 64 targets in total) and to find clocks displaying a predetermined time amongst other distractor clocks (single-target search; 40 targets in total). NPs were significantly poorer than the SCs and OACs at identifying contralateral targets on all tasks but had high accuracy for ipsilateral targets. Interestingly, NPs made contralateral saccades to the same extent as the control groups. In line with previous research (e.g. Walker, & Young, 1996), NPs spent a smaller proportion of the total trial time fixating the contralateral regions. Additionally, a disproportionate amount of time was spent scanning ipsilaterally, suggesting hyper-attention to this area. This sampling deficit was further exacerbated by higher cognitive load (i.e. dual-search). Importantly, during completion of the clock cancellation tasks, average contralateral gaze durations (time spent fixating a region before transgressing a region boundary), but not ipsilateral gaze durations, were significantly inflated compared to controls. This is indicative of problems associated with processing (encoding or representing) information in this region. The results not only provide support for biased visual sampling in neglect, but also demonstrate that during contralateral visual sampling, disruption in processing was evident. This has implications for the efficacy of interventions that shift involuntary eye movements into the neglected area (e.g. prismatic adaptation), as even when neglect patients visually sample information, they often still fail to perceive it.

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43.307 **Online Ocular Artifact Detection and Rejection** Cameron Hassall[1](cameron.hassall@dal.ca), Chelsey Michaud[1], Olave Krigolson[1]; [1]Psychology and Neuroscience, Dalhousie University

Electroencephalographic (EEG) data is often plagued by artifacts due to the muscle activity associated with unwanted eye movements. Current strategies for dealing with ocular artifacts focus on three approaches: rejection, correction via regression techniques, or correction via independent component analysis (ICA). While regression (e.g. Gratton, Coles, and Donchin, 1983) and ICA do a reasonable job of removing the effects of eye movements from EEG, these techniques are only able to provide an estimate of the underlying data. Here, we tested a trial-rejection strategy in the context of a reward-processing task in which participants received feedback after estimating the length of one second. Using a custom MATLAB script we developed to display summaries of EEG data surrounding participant responses, a research assistant accepted or rejected each trial based on peak voltage, peak voltage change, and a visual inspection of the waveform. Using this rejection protocol, our data was free of ocular artifacts and, after subsequent analysis, resulted in event-related potentials that were less variable in both peak magnitude and temporal stability, compared to when ocular artifacts were corrected using traditional regression or ICA methods. Interestingly, we noted that our trial rejection strategy resulted in a slight bias towards correct trials (trending towards significance) suggesting that participants made more eye movements following error feedback compared to correct feedback. This bias, if present, would impact any EEG analysis, regardless of how ocular artifacts were handled. The proposed technique, however, offers three advantages: fewer ocular artifacts in the resulting EEG, less variability in the resulting ERPs, and an elimination of the need for ocular correction.

Acknowledgement: National Sciences and Engineering Research Council of Canada

43.308 **Camera-based eye tracking improves the signal-to-noise ratio of EEG** Jason Satel[1](jsatel@gmail.com), Cameron Hassall[2], Olav Krigolson[2], Raymond Klein[2]; [1]Faculty of Computer Science, Dalhousie University, [2]Department of Psychology, Faculty of Science, Dalhousie University

To examine event-related potentials (ERPs) - the brain responses associated with specific sensory, cognitive, and motor processes - researchers record brain activity using electroencephalography (EEG) while participants perform carefully designed tasks. EEG is inherently noisy, hence ERPs are derived by averaging over many trials. Since eye movements and blinks generate large electrical signals that contaminate EEG, methods have been developed to deal with these artifacts. Electrooculography uses activity from electrodes near the eyes to identify and remove contaminated trials, or participants who move their eyes too often. This method reduces reduces the signal-to-noise ratio and/or increases the number of participants required. Mathematical techniques, such as independent component analysis, have been used to allegedly remove eye movement activity. However, it is unclear whether all such activity is definitively removed, while leaving the neural activity of interest unaltered. Moreover, this approach necessarily includes trials with eye movements, often contrary to task requirements. In four recent experiments combining camera-based eye tracking and EEG, we demonstrated the potential of combining these technologies to increase ERP data quality. We used a cueing task where participants maintained fixation, ignored or made eye movements to uninformative exogenous or endogenous cues, then made manual localization responses to targets. Eye tracking ensured appropriate oculomotor behavior at all times. Error messages were presented when incorrect eye movements were observed and such trials were recycled. The ERPs were much cleaner (enhanced signal-to-noise ratio) here, relative to similar experiments without concurrent eye tracking. There are at least two (not mutually exclusive) explanations for this observation: a) participants learn to learn to control their oculomotor behavior through online feedback, minimizing untoward blinks and eye movements, and b) eye monitoring allows more accurate categorization of trials to be excluded than traditional techniques.

43.309 **Co-registration of eye movements and event-related potentials in reading** Joseph Schmidt[1, 2](schmidtjoseph@hotmail.com), Steven G. Luke[1, 2], John E. Richards[1, 2], John M. Henderson[1, 2]; [1]Department of Psychology, University of South Carolina, [2]Institute for Mind and Brain, University of South Carolina

Eye-tracking has become a nearly ubiquitous tool that provides an online measure of information processing across a variety of tasks. Likewise, event-related potentials (ERPs) provide an online measure of neural processing. Recent work has attempted to combine these techniques and co-register the eye movement record with the electroencephalography (EEG) waveform, allowing for the analysis of ERPs time locked to fixation onset. However, an impediment has been eye-movement-related EEG artifacts(e.g. Dimigen, Sommer, Hohlfield, Jacobs, & Kliegl, 2011). Our method for co-registration uses Independent Components Analysis (ICA) to identify and remove the components resulting from eye movement activity. After removal, the residual EEG activity was reconstructed and analyzed for fixation related ERPs. The eye movement components were identified using three criteria: (1) the component loadings on the surface of the head were consistent with an eye movement; (2) source analysis localized the component to the eyes, and (3) the temporal activation of the component occurred at the time of the electrooculogram activity in the eye and differs for right and left eye movements. This method was tested in the context of a connected text reading paradigm in which observers read paragraphs of normal text or pseudo-text. In the normal text condition subjects read paragraphs, whereas in the pseudo-text control condition observers "read" through a font in which each letter was replaced by a geometric shape that preserved word location and word shapes but eliminated meaning (see Henderson & Luke, 2012). The corrected EEG waveform was aligned to word fixation onset and early results suggest P1 and N1 differences between text and pseudo-text conditions as well as trends towards frequency effects in the text condition. These results suggest that the co-registration of eye movements and ERPs can be successfully combined to investigate a wide variety of tasks.

Acknowledgement: 1-National Science Foundation (BCS-1151358) to John M. Henderson 2-National Institutes of Health, NICHD, R37 HD19842

43.310 **iMap Motion: Validating a Novel Method for Statistical Fixation Mapping of Temporal Eye Movement Data** Yingdi Liu[1](yingdi.liu@unifr.ch), Junpeng Lao[1], Sébastien Miellet[1], Gustav Kuhn[2], Roberto Caldara[1]; [1]Department of Psychology, University of Fribourg, Fribourg, Switzerland, [2]Department of Psychology, Goldsmiths College, London, United Kingdom

The visual system is equipped with the most sophisticated machinery to effectively adapt to the world. Where, when, and how human eyes are moved to gather information to adapt to the visual environment has been a question that has fascinated scientists for more than a century. However, research in visual cognition and in eye movements has primarily relied on the use of static images, which are fairly impoverished representations of real-life situations. At least for eye movements, this methodological limitation might arise from the difficulty of using videos as visual inputs (since they engender a large quantity of data), but also by the absence of computational tools performing adequate statistical analyses on 3D dataset (i.e., 2D

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images over time). To overcome this limitation, we adapted iMap (Caldara and Miellet, 2011), a robust data-driven method that generates statistical fixation maps on 2D images. We developed a novel data-driven method that does not require a priori segmentation of video frames into Regions of Interest and isolates statistical significant fixation contrasts over time: iMap Motion. To validate the technique, we recorded eye movement data on two well-established paradigms, involving the viewing of dynamic magic tricks (Kuhn and Tatler, 2005). After extracting fixations, the data were smoothed by convoluting Gaussian kernels to generate three-dimensional fixation maps at each frame. We then applied the statistical Random Field Theory to correct for multiple comparisons. Finally, we assessed significant fixation differences in this 3D search space by tracking the peak intensity of the statistical contrasts of interest over time: the success or failure in detecting the magic tricks. iMap Motion automatically identified the maximum fixation contrasts, which were related to fixations misdirected from the location of the tricks. These observations posit the method as an effective tool to isolate meaningful fixation differences in temporal eye movement data.

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43.311 **An information theory based technique to improve eye fixation clustering and salient region discovery** Harish Katti[1](harish2006@gmail.com); [1]Center for Neuroscience, Indian Institute of Science

Eye-tracking studies over static scenes typically yield a large number of fixations that need to be grouped into meaningful clusters to obtain salient regions of human interest. Such salient regions give valuable insights about top-down and bottom-up cues in the visual scene. I develop an information theory based measure, to improve the detection of salient regions from eye fixation data over social and natural scenes with multiple entities of human interest. Eye fixation clustering approaches typically rely on (a) prior knowledge of number of clusters and distance based thresholds [Santella et. al., ETRA, 2005] (b) priors on typical object sizes and inter-object distances to identify long saccades that might land on new regions [Katti et. al. ACM MM, 2010] (c) thresholds on visual conspicuity to detect modes in smoothed fixation distributions [Judd et. al., ICCV, 2009]. My method uses KL divergence to assess information gain due to changes in the distribution of regions of interest discovered by different threshold values for methods of type (a), (b) and (c). For each scene with accompanying eye fixation data, clusters arising out of successive threshold choices 'i' and 'i+1' are converted into continuous probability distributions Di and Di+1. Cumulative sum of absolute KL divergence values ∑ abs(KL(Di+1 || Di)) over successive threshold choices 'i' and 'i+1' are then computed, this cumulative sum grows slowly over threshold choices that can reliably estimate clusters embedded in the fixation data and in turn helps to identify a good range of choices for threshold. Additionally, this measure can also score scenes for the presence of strong visual structure arising out of social and affective cues or aesthetic placement of visual elements. Analysis over scenes from three large scale public eye-fixation datasets demonstrates effectiveness of the proposed measure, illustrative results have been provided as supplementary material.

43.312 **Visual fixation parameters predict decisional outcomes better than preference** Eve Isham[1,3](eaisham@ucdavis.edu), Joy Geng[1,2,3]; [1]Center for Mind and Brain, [2]Department of Psychology, [3]University of California, Davis

Although visual fixations are commonly used to index stimulus-driven or internally-determined preference, recent evidence suggests that visual fixations can also be a source of decisional bias that moves selection toward the fixated object (Krajbich et al, 2010). These contrasting results raise the question of whether visual fixations always index comparative processes during choice-decision tasks, or whether they might better reflect internal preferences when the decision does not carry any economic or corporeal consequences (Rangel et al, 2008). In two experiments, participants were shown pairs of novel black and white patterns and asked to choose which was more aesthetically pleasing (Exp.1; N=20) or appeared more "organic" (Exp.2; N=20). Participants also provided independent aesthetic (i.e., preference) ratings of the stimuli. The behavioral responses were used to classify each stimulus as chosen or unchosen, and as being rated higher, lower, or the same as its pair. Total fixation durations were subjected to a 2 (chosen vs unchosen) x 3 (higher, lower, same) within-subjects ANOVA. Our results demonstrated that longer fixation durations were correlated with the chosen item (p<.001), but not the more preferred item (p>.1). Moreover, a significant difference in cumulative fixation times on the subsequent choice was observed as early as 1000 to 2000 ms before the choice was actually indicated with a button press. Similarly, final fixations were more likely to be on the chosen object than the unchosen one (p<.001). Collectively, these results suggest that fixation parameters such as total looking durations and final fixations are a better index of choice than of aesthetic preference when participants must make an explicit choice.

43.313 **Pupillometry as a method for tracking shifts in control state during visual relational reasoning** Taylor R. Hayes[1](hayes.335@osu.edu), Alexander A. Petrov[1]; [1]Ohio State University

The ability to adaptively shift between exploration and exploitation control states is a critical component in the optimization of behavioral performance (Cohen, McClure, & Yu, 2007). Converging evidence from primate electrophysiology and computational neural modeling have indicated that changes in exploratory versus exploitive control state may be mediated by the broad noradrenergic projections emanating from the Locus Coeruleus (LC). The synthesis of these findings has resulted in the development of a theory of LC function (adaptive gain theory, Aston-Jones & Cohen, 2005) in which the LC modulates the gain of cortical units to facilitate either exploration or exploitation in response to current assessments of task utility. The pupillary response is strongly correlated with LC activity in primates (Rajkowski et al.,1993) and can be used as a non-invasive proxy to assess fluctuations in LC activity in humans. Ten participants completed fourteen visual analogies from Raven's Advanced Progressive Matrices Test while pupillary response and verbal protocols were recorded. Pupil diameter was measured continuously using an Eyelink 1000 eye tracker at a sampling rate of 250 Hz. Think aloud verbal protocols were used to identify periods of exploration within each trial. The results showed that during periods of high exploration there was a larger pupillary response compared to other periods. These findings are consistent with the LC's role in modulating exploration-exploitation tradeoffs as postulated by adaptive gain theory. Moreover, our results suggest that the human pupillary response may be able to serve as a useful tool for identifying shifts in control state during online processing.

Acknowledgement: Supported by the National Eye Institute

Visual memory: Objects, features

Monday, May 13, 8:30 am - 12:30 pm

Poster Session, Royal Ballroom 6-8

43.314 **Ensemble-based Change Detection** Robert Eisinger[1](reising1@jhu.edu), Hee Yeon Im[1], Hrag Pailian[1], Justin Halberda[1]; [1]Johns Hopkins University

Objects and ensembles have independently been the focus of much investigation, but it remains to be determined how they are related. We have been investigating the possibility that ensembles function as single units for visual attention and memory – similar to single objects. Here, using one-shot change detection, we find that multiple ensembles can be stored and multiple features can be retained for each ensemble group. We find similar results for individual objects (a replication of Luck & Vogel, 1997). This pattern of results is consistent with the suggestion that an ensemble group behaves as a single item for VWM. Luck & Vogel (1997) demonstrated that memory for items with four features (conjunction) is equivalent to memory for items with a single feature. We replicated this result and adapted this experiment to test the nature of ensembles. Participants were presented with a memory display consisting of either 2 or 4 items (or 2 or 4 ensembles). Both items and ensembles varied on multiple dimensions (e.g., orientation, number, color, size). In the single feature condition, subjects were instructed to attend to a particular feature (e.g., only orientation could change). In the conjunction feature condition, subjects were instructed to attend to all features. After a consolidation period, a test display appeared and participants had to determine whether a change had occurred. The results replicated those of Luck and Vogel (1997) for items with similar results for ensembles. That is, subjects remembered both single features and conjunctions for both individual items and ensembles. We take these results to support the proposal that ensembles are treated in the same manner as individual objects for visual working memory.

43.315 **Visual Processing Stages: Beyond Two Seconds** Jane Jacob[1](jjacob9@uh.edu), Bruno Breitmeyer[1,2]; [1]Dept of Psychology, Univ of Houston, [2]Center for Neuro-Engineering & Cogntive Science, Univ of Houston

To estimate the time course of iconic and post-iconic visual processing stages for form and/or color features, the results of two experiments using priming and comparison tasks were examined. In these experiments a prime preceded a probe at varying stimulus onset asynchronies (SOAs) and observers reported the form or color feature of the probe in the priming task, and whether or not the probe differed from the prime in the comparison task. In the first experiment (Jacob & Breitmeyer, 2012) prime-probe SOAs ranged from 0 to 1920 ms, and in the second from 253 to 4000 ms. The

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first experiment showed evidence for three processing stages: iconic visible persistence (0-130 ms), iconic informational persistence (130-700 ms), and visual working memory (VWM) (700-2000 ms). In the second experiment, comparison effects suggest the existence of an additional fourth stage of visual processing (2000-4000ms), possibly also in VWM. Additionally, priming effects in the first experiment show rapid decline after a peak at 133ms, and little, if any, priming effect past 650ms (consistent with Mattler, 2005). In contrast, priming effects in the second experiment last two times longer, ending around 1400 ms, suggesting that observers adopt different strategies for storing information briefly in sensori-motor memories; specifically, in priming tasks ranging over progressively longer SOAs, observers retain sensori-motor representations over longer intervals. Overall our data also suggest that the temporal dynamics of information processing differs due to 1) the existence of different processing stages in VSTM and 2) the SOA range at which processing in these stages is sampled.

43.316 **Working memory modulates unconscious visual processing** Dong Liu[1](liud@psych.ac.cn), Li Wang[1], Yi Jiang[1]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Psychology, Chinese Academy of Sciences

Previous studies have demonstrated that the content of working memory (WM)can modulate conscious visual selection.Whether WM can affect the unconscious processing of visual signals has received much less attention. Here we probed this issue by combining the delayed match-to-sample task with an interocular suppression paradigm. A face (with fearful or neutral expression) was memorized for later facial identity recognition.During the delay period,a standard high contrast dynamic noise pattern was presented to one eye, and a new test face (with fearful or neutral expression) was gradually introduced to the other eye so that it was rendered invisible through interocular suppression at the beginning of each trial. We measured the time for the test face to break from noise suppression and begin to gain dominance. Results showed that the faces matched the emotional valence held in WM emerged from suppression into awareness faster than those did not match.This facilitation effect could not be accounted for by an automatic bottom-up perceptual priming mechanism,as the effect disappeared when these faces were passively viewed and not held in WM. Moreover, this WM induced enhancement can be extended to more basic visual features (e.g.,orientation). Taken together, the findings suggest that reentrant feedback from WM can modulate the unconscious processing of both high-level and low-level visual signals. Keywords:working memory, visual awareness,emotion, continuous flash suppression

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43.317 **Changing a memory is dissociable from forming a new memory** Hyunyoung Park[1](hyunyoung.park@vanderbilt.edu), Geoffrey F. Woodman[1], Adriane E. Seiffert[1]; [1]Department of Psychological Sciences, Vanderbilt University

A long-standing tradition of memory research is to describe memory as a serial process, in which memory successively accumulates new information (Sternberg, 1969; Shiffrin & Schneider, 1974; Farrell & Lewandowsky, 2002). Memory also has been described as including a flexible system that can modify stored information (Baddely, 1986; Morris & Jones, 1990; Woodman, Vogel, & Luck, 2012). When we change a memory, do we successively overlap new information on old information or do we actually replace old information with new information? To test this idea, we asked participants to memorize sample arrays of 1 to 5 colored dots and to perform three different tasks. In the rehearsing task, an asterisk appeared in one of the sample array locations, and participants had to rehearse the color at that location. In the adding task, a new colored dot appeared in a new location, and participants had to add the new colored dot into their memory. In the changing task, a new colored dot appeared in one of the sample array locations, and participants had to change their memory at that location to the color of the new colored dot. Finally, participants reported all colors in their most recent memory by choosing the colors from an array of all possible colors. Performance was impaired as set size increased ($F(4,16)=39.858$, $p<.001$). Rehearsing performance was better than adding ($F(1,19)=9$, $p<.008$), showing a cost of forming a new memory. However, adding performance was better than changing ($F(1,19)=12.617$, $p<.003$) and this difference became larger at a larger set size (interaction $F(4,16)=5.37$, $p<.007$), showing an additional cost of changing a memory. These results were replicated in a separate experiment blocking each task. The findings show that changing a memory is not the same as forming a new memory, but instead is a more demanding process.

43.318 **Properties of high-fidelity visual working memory representations for orientation** Rosanne L. Rademaker[1](rosanne.rademaker@maastrichtuniversity.nl), Ilona M. Bloem[1], Peter De Weerd[1,2], Alexander T. Sack[1]; [1]Cognitive Neuroscience department, Maastricht University, Maastricht, The Netherlands, [2]Radboud University Medical Centre Nijmegen, Donders Institute for Brain, Cognition and Behaviour, The Netherlands

Visual working memory serves as a highly efficient buffer for maintaining information that can no longer be accessed directly. While most investigations have emphasized the capacity limitations of working memory, here we investigated the fidelity of remembered visual representations when memory load is kept well within capacity confines. First, we examined memory fidelity for the orientation of a grating, and whether it changes over time. Participants were briefly shown a randomly oriented grating that was remembered for 1-12 seconds, after which they reported the orientation in memory by method-of-adjustment. Memory for a single orientation proved highly stable, with a $<2^{o}$ increase of response variability when comparing the shortest and longest intervals. No evidence was found to imply forgetting of orientation information, even at very long retention intervals. Next, we introduced a second, to-be-ignored grating, presented midway through a fixed retention interval. We parametrically varied the orientation of this task-irrelevant grating relative to the orientation in memory. We found a reliable ($2\text{-}3^{o}$) shift in participant's response distributions, towards the orientation of the irrelevant grating. Thus, despite explicit instructions to ignore the irrelevant second grating, orientation information present in this stimulus exerted a systematic bias on participant's responses. We investigated the role of attention in another experiment by making the second grating task-relevant – it was probed with equal probability as the first grating. This almost completely abolished the bias exerted by the second grating on responses to the first. Interestingly, when the second grating was probed, a stable shift towards the orientation of the first grating was still present. Our results suggest that visual working memory for orientation, while robust, displays a small but systematic bias towards task-irrelevant information that conflicts with same-feature information being held in memory.

43.319 **Perceptual Organization Influences Memory, Search, and Aesthetic Judgment** Karen B. Schloss[1](kschloss@berkeley.edu), Madeline McComb[1]; [1]Department of Psychology, University of California, Berkeley

According early Gestalt Psychologists, the organization within a stimulus can strongly influence memory (Köhler, 1947; 1958). In this study, we tested how perceptual grouping among elements in a visual display influences memory for paired associations (Experiment 1). Participants were shown a display containing four fictitious molecules, along with their names for 15 sec, and were asked to remember the name of each molecule and how many "spokes" it had. Following a 12-sec delay of counting backwards aloud, participants were prompted with one of the names and were asked to report the corresponding molecule's number of spokes. Memory was better when the associated elements (molecule—name pairs) were more strongly grouped by proximity (Wertheimer, 1932) and common region (Palmer, 1992) during study. One possible explanation for this effect is that the more strongly grouped displays were organized more rapidly, leaving more time for encoding. We tested this hypothesis using a visual search task (Experiment 2). While the displays from Experiment 1 remained on the screen, participants were prompted with one of the molecule's names and were asked to report how many spokes it had. Participants were faster and more accurate when searching in displays with more strongly grouped molecule—name pairs. Therefore, faster organization may account for the memory effects observed in Experiment 1. Given previous evidence that aesthetic preferences increase with ease of processing, or perceptual fluency (e.g., Reber et al., 2004), we hypothesized that people would also aesthetically prefer the strongly grouped displays from Experiments 1 and 2. When asked to judge aesthetic preferences for these displays in a 2AFC task, participants did indeed prefer displays that were easier to remember and facilitated faster search (Experiment 3). Our results indicate that there are important interactions between perceptual organization and higher-level cognition (e.g., memory and aesthetic judgments).

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43.320 **Learning beyond the prototype: Implicit learning of principal components in dot patterns** Xiaoqing Gao[1](xgao@cvr.yorku.ca), Hugh Wilson[1]; [1]Centre for Vision Research, York University

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Humans have the ability to implicitly learn the central tendency of a group of visual objects (the prototype effect, Posner & Keele, 1968). A recent study (Gao & Wilson, 2012) demonstrated that in addition to the prototype, adults also implicitly learn the feature correlations that capture the most significant variations among faces as defined by principal components (PC). However, it is unclear if the implicit learning of PC is specific to faces. In the current experiment, adults (n=13) studied 16 patterns each consisting of 9 dots. The 16 patterns deviated from a prototype in a systematic way so that the first PC explained 50% of the total variance. After participants studied the 16 patterns for 40 seconds each, their memories were tested in a studied/novel recognition task with the 16 studied patterns plus 16 new patterns that deviated from the prototype in orthogonal directions to the studied patterns. Participants also gave studied/novel judgments to the prototype pattern, and two patterns that deviated from the prototype on the positive and negative directions of the first PC of the 16 studied patterns. All the patterns have the same distance from the prototype. Participants recognized 59% (above chance, $p < 0.01$) of the studied patterns and misidentified 43% (below chance, $p < 0.05$) of the new patterns. As would be explained by the prototype effect, they recognized the unseen prototype 80% of the time. Interestingly, they also recognized the two unseen patterns representing the changes on the first PC 71% of the time. The recognition rates for the prototype and the two PC patterns were all higher than for the studied patterns ($ps < 0.05$). The results suggest the implicit learning of the prototype and the most significant feature correlations as defined by PC is a general mechanism in visual object recognition.

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43.321 **Visible persistence in transient random dot stimuli**

Kathrin Thaler[1](k.thaler@uni-muenster.de), Maximilian Bruchmann[1]; [1]Institute of Biomagnetism and Biosignal Analysis, University of Muenster, Germany

Visible persistence (VP) is defined as the prolonged percept of a visual stimulation continuing after the physical termination of the physical stimulus itself. In the past, great effort has been spent investigating VP of stimuli with minimal physical duration. In this study, we created a novel kind of visual stimulus consisting only of a single transient luminance signal, and thereby examined an extreme case of minimal duration. In two experiments subjects were repeatedly shown two successively presented random dot matrices. Both matrices consisted of 1024 □ 768 randomly placed black and white pixels. On the transition from one array to the second, all pixels within a certain area reversed luminance polarity. Phenomenologically, the reversal produces the percept of an object (shaped like the area within which the pixels' polarity was changed) with an abrupt onset and a gradual decline. We measured VP duration of these transient shapes by asking subjects to match the onset of an auditory or visual reference stimulus to the onset and offset of the perceived shape. To explore the influence of spatial parameters on VP we presented annuli as transient shapes in our first experiment. The annuli were presented centrally and varied in size (inner radius) and thickness. VP increased with stimulus size and decreased with annulus thickness, suggesting that retinal position as well as the size of the surface area may influence VP. Thus, in a second experiment, we systematically varied the eccentricity and the radius of transient discs. The results show in interaction of size and eccentricity, indicating a non-monotonic relationship between spatial parameters and VP. We conclude that in order to explain VP durations, spatio-temporal receptive field properties but also higher-level mechanisms, especially filling-in, have to be taken into account.

43.322 **Congruence with items held in visual working memory boosts invisible stimuli into awareness: Evidence from motion-induced blindness**

Hui Chen[1,2](psychenhui@gmail.com), Brian Scholl[2]; [1]Department of Psychology, The Chinese University of Hong Kong, [2]Department of Psychology, Yale University

Attention and awareness are intimately related — with the former sometimes serving as a gateway to the latter, as in phenomena such as inattentional blindness. Other recent work suggests that attention and visual working memory (VWM) are also intimately related. For example, objects that are congruent with items held in VWM tend to attract attention. Combining these insights leads to the intriguing possibility that VWM congruence could make otherwise-invisible stimuli visible. We tested this by exploiting Motion-Induced Blindness (MIB), wherein salient targets fluctuate into and out of conscious awareness in the presence of a superimposed global motion pattern. A single number was presented at the beginning and end of each trial, and observers had a simple VWM task: Was the final number the same as the initial one? During retention, observers viewed an MIB display with two targets (in the two upper display quadrants), each the number '8' drawn as a rectangle with a single bisecting line. Observers held down independent keys to indicate when the two targets disappeared. While both were invisible, line segments on each target gradually faded out to yield two other numbers (e.g. "5" and "2"), one of them congruent with the VWM number. After the two targets reappeared, observers indicated which of them (left, right, or both) had become visible first. Whether the VWM number was a numerical digit or a written word, the VWM-congruent target was more likely to reappear first — an effect not due to endogenous attention (since observers didn't know which invisible target would be congruent until it reappeared) or to a response bias (since it did not occur in catch trials that forced simultaneous reappearance). This discovery shows how VWM congruence can boost invisible stimuli into awareness, and suggests new types of interactions between VWM, attention, and awareness.

43.323 **Object persistence enhances spatial navigation in visual menus: A case study in smartphone vision science**

Brandon Liverence[1](brandon.liverence@yale.edu), Brian Scholl[1]; [1]Department of Psychology, Yale University

Disruptions of spatiotemporal continuity in dynamic events impair many types of online visual cognition (e.g. change detection, multiple object tracking), suggesting that persisting objects serve as underlying units of attention and working memory. Can persistence also constrain visual learning over time, and could this make a difference in real-world contexts? We explored the role of persistence in spatial navigation through virtual scenes, using a novel "menu navigation" paradigm inspired by smartphone interfaces. Observers viewed "icons" (real-world object pictures) spatially organized into virtual grids that remained stable across all trials in a block. Only a subset of icons was visible at a time, viewed through a virtual window. On each trial, subjects navigated through the grid (via keypresses) to find 4 randomly-chosen target icons, in order, as quickly as possible. On Persist blocks, icons slid smoothly from page to page (mimicking many smartphone animations). On Fade blocks, icons were replaced by a fading animation with no motion (equating brute duration). Across many variations, subjects were significantly faster on Persist blocks — often by several seconds/trial. This difference occurred for both simple displays (e.g. grids of 4x4 pages with 1 visible icon/page) and for displays that more closely mirrored smartphone interfaces (e.g. grids of 3x3 pages with 4 visible icons/page.). It also occurred even towards the end of each block (after performance had reached asymptote), suggesting a reliance on robust implicit spatial representations (during Persist blocks) that could not be matched by explicit memorization (during Fade blocks). Further conditions verified that this result reflected object persistence per se, rather than attention capture, distraction, or momentary disappearance due to the fading. These results suggest that object persistence can control spatial learning over time as well as online perception, and they show how vision science can provide a foundation for understanding computer interface design.

43.324 **Context messes with massive memory**

Karla K Evans[1,2](kevans@search.bwh.harvard.edu), Jeremy M Wolfe[1,2]; [1]Brigham and Women's Hospital, [2]Harvard Medical School

Humans are capable of remembering massive numbers of objects or scenes with surprisingly precise recollection of details. What happens if we try to memorize clearly specified objects in scenes when the rest of the display is irrelevant or distracting? Here we report that, curiously, memory for individual objects is impaired when those objects are presented in scenes that are irrelevant to the observer's task. We asked observers to memorize single objects on blank backgrounds, in arrays of objects, or appropriately embedded in real scenes, but clearly marked by an outline box. As in previous work, objects, presented in isolation, are remembered very well (d=2.27). Performance was significantly reduced when these same objects were presented in a random array of irrelevant objects (d'=1.71). If the irrelevant objects were different at retrieval, performance was lower (d'=1.38) though not significantly. Performance was reduced to d'=1.40 when objects were embedded in real scenes, even though they were clearly marked. If observers learned objects in one scene context and were tested with the objects in a different context, performance was very poor (d'=0.64) even though scene contexts were irrelevant. When we made the objects perceptually stand out from the background scene by pasting them into the scene in a white box the performance sis not improve (d'=0.69). Scene context interfered even if the target objects were incongruent to the scene context (d=1.13). Performance was worse if the scene context was present only at encoding (d'=0.64) than when present only at retrieval (d'=1.34). Apparently, when trying to remember one part of a display, observers are unable filter out additional information even when it is irrelevant. The rapid, effective encoding that makes scene memory so easy, appears to be obligatory and to be a source of interference when observers try to ignore part of that scene.

Acknowledgement: NEI Grant EY17001

43.325 **Visual search for multiple targets remains efficient when supported by recollective long-term memory** Emma B. Guild[1](emma.guild@mail.utoronto.ca), Jenna M. Cripps[2], Naseem Al-Aidroos[2]; [1]Psychology, Arts & Science, University of Toronto, [2]Psychology, CSAHS, University of Guelph

We are often faced with the task of searching our visual environment for multiple objects, such as when searching for any one of our friends at Club Vision. To accomplish this search we must retrieve information stored in long term memory (LTM). Surprisingly, searching through memory adds little cost to the efficiency of visual search. That is, visual search response times increase logarithmically with the number of targets stored in LTM (Wolfe, 2012, Psychol Sci): It doesn't take much longer to search for sixteen friends than it does to search for eight. In this previous investigation, memorized targets were both perceptually identical to the visual search targets, and repeated frequently throughout the search task on target present trials. These conditions are conducive to a familiarity-based LTM process, which may have driven the efficiency of search. In the present study, we evaluated whether LTM-supported search remains efficient when based on flexible, abstract memory representations (i.e., recollection, rather than simple judgements of familiarity). Participants memorized 1, 2, 4, 8 or 16 targets, counterbalanced across blocks, and searched for these targets amidst twelve on-screen distractors. Experiment 1 used predominately target-absent trials and blocks terminated after the first successful target-present trial, ensuring that familiarity did not accrue over repeated presentations of the target. In Experiment 2, this task was extended by having participants memorize written object names and visually search for pictures of those objects, thereby eliminating perceptual familiarity. Despite these restrictions on the contribution of familiarity, we continued to see the efficient logarithmic relationship between visual search time and memory set size. These data suggest that interactions between visual search and LTM search are not completed solely based on familiarity; rather, participants can engage a recollection-based LTM process, calling upon flexible memory representations to support efficient visual search, even for previously unobserved information.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada

Perceptual organization: Grouping

Monday, May 13, 8:30 am - 12:30 pm

Poster Session, Orchid Ballroom

43.401 **Visual and emotional analysis of symmetry** Alexis Makin[1](alexis.makin@liverpool.ac.uk), Anna Pecchinenda[2], Marco Bertamini[1]; [1]Department of Experimental Psychology, University of Liverpool, [2]Department of Psychology, University of Rome

Visual symmetry is closely related to subjective beauty. We studied the links between symmetry detection and emotion, focusing on the question of when symmetry is emotionally evaluated. In one study, we found that symmetrical patterns speeded classification of positive-valence words, while random patterns speeded responses to negative words. This emotional priming effect was only apparent when participants explicitly attended and classified the patterns, and not when they attended to another dimension of the same stimuli (Bertamini et al., under review, Cognition). In a second study using the Implicit Association Test (IAT), we found that response time was faster in congruent blocks (when the left key was used to report symmetry and positive words, and the right key was used to report random and negative words), than in incongruent blocks, when the response mapping was reversed (random and positive, symmetrical and negative). This is a type of implicit preference for symmetry. Additional IAT studies found cases where implicit preferences diverged from preferences in an explicit rating task, but implicit preferences were always linked to visual salience (Makin et al., Emotion, 2012). In a third study, we measured electrophysiological responses to symmetrical and random patterns. These patterns produced different ERPs, which could be localized to activations in the bilateral visual regions. This symmetry-related ERP was most pronounced for reflectional symmetry (see supplementary material). The facial muscle responsible for smiling (Zygomaticus Major) was more active when participants viewed reflection than random patterns, however, this response was sensitive to task completion, rather than the simple presence of symmetry (Makin et al., 2012, Neuropsychologia). Putting all results together, we conclude that visual symmetry has positive valence which is linked to processing fluency. However, symmetry is only emotionally evaluated when it is attended to and classified, and not under passive viewing conditions.

Acknowledgement: This work was supported by the Leverhulme Trust

43.402 **Illusory motion and motion capture for various numbers of superimposed elements in terms of oblique components.** Makoto Ichikawa[1](ichikawa@L.chiba-u.ac.jp), Yuko Masakura[2]; [1]Department of Psychology, Chiba University, [2]Center for Hyper Media Research, Tokyo Polytechnic University

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 amount of superimposed elements affect the illusory rotation for the circles (150mm in diameter) and motion capture for the superimposed elements. The inner and outer rings each consist of 72 oblique black lines on a white background. Each line was tilted radially by 30 degree. The amount of superimposed element, which were arc-shape with intersection angle of 9 degree, ranged from 0 to 40. Observers viewed the stimuli by repeatedly moving the head forward and backward at a rate that felt comfortable. Observers reported the direction of the rotation (clockwise or anticlockwise when approaching the figure), and evaluated the magnitude of the illusory motion for the inner circle and superimposed elements. While the illusory rotation for the circles mostly decreased at the middle range of the amount of superimposed elements, that for the superimposed elements increased monotonically with the increment of elements. These results suggest that the motion capture is not caused by perceptual dragging of the superimposed elements by the motion illusion for the oblique lines. Rather, the motion capture for the superimposed elements is caused by the local leakage of motion signal from the oblique components, and accumulation of the motion signal at each superimposed element.

Acknowledgement: Japan Society for Promotion of Science Grant 21530760

43.403 **Artificial Neural Networks Susceptible to Geometric Visual Illusions** Steven R. Holloway[1](srh@asu.edu), Flavio J.K. da Silva[1], Michael K. McBeath[1]; [1]Department of Psychology, College of Liberal Arts and Sciences, Arizona State University

Perceptions of real objects tend to differ from the actual physical form of the object in many critical ways as exemplified by humans' tolerance of spatial inconsistencies and the prevalence of robust spatial and kinetic illusions. Such phenomena have been suggested to be byproducts of complicated mathematical computations or errors in neural mapping. Here, we show that a basic parallel distributed processing network that was trained to recognize shapes is susceptible to illusory contour-style illusions. The network learned to identify shapes accurately and robustly given only unambiguous sensory input. When tested with Kanizsa triangle-type illusions, the network made systematic "errors" when identifying shapes that were consistent with human visual illusions. Shape recognition occurs when various features of an image have been processed by distributed networks that seem to specialize in certain types of features (e.g., edges, angles, colors, moving edges). Higher centers then "recognize" when stimuli from feature processing areas reach a critical mass. Our data suggest that the distributed nature of the information-processing in our network may also contribute to "machine illusions." Natural stimuli tend to be ambiguous, and this ambiguity is resolved by matching the actual stimuli with known images based on past visual experience. Since resolving stimulus ambiguity is a challenge faced by all visual systems, a corollary of these findings is that humans might experience illusions because of a similar mechanism. The data might also provide an alternate definition of illusion: The extent to which a true stimulus matches the stored image which the stimulus most likely appears to be. Accordingly, illusions may not be fundamentally different from non-illusory percepts, both being direct manifestations of the relation between images and what the images are expected to be.

Acknowledgement: None

43.404 **Re-pairing: Perceptual reorganization of moving visual patterns from sensory fusion.** Alan Ho[1](aho@ambrose.edu), Stuart Anstis[2]; [1]Department of Behavioral Science, Ambrose University College, [2]Department of Psychology, UC San Diego

Crossed gratings moving behind an aperture are often seen as a single moving 2D plaid (Adelson & Movshon, Nature 1982). We report here when two distinct moving 2D plaids that are made of four crossed moving gratings of similar physical properties but different orientation (hence lacking a common velocity vector) are superimposed inside a single aperture, the moving grating components can radically reorganize immediately, yielding

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two completely new and distinct plaids that are seen to move in different directions on two transparent planes. Such spectacular image self-reorganization can even emerge when observers view two dichoptically presented monocular plaids (inside a 10o circular aperture) that are made up of non-rivalrous square wave gratings of low spatial frequency (0.2 cpd), low luminance contrast (10 – 20%), and moving at a speed of 1 deg/sec. As a result of sensory fusion, two distinct, new cyclopeanly perceived 2D plaids are seen in transparent motion. In the dichoptic case, the predominant cyclopeanly seen moving plaids can arise from interocular exchange of components ('re-pairing') from the monocular plaids. This exchange underlying image self-reorganization happens if and only if it minimizes perceived motion. Thus, if the left eye views a moving 30o plaid consists of gratings oriented at 0o and 30o, and the right eye views another moving 30o plaid consists of gratings oriented at 70o and 100o, observers perceive two 70o plaids (the 0o grating of one eye re-pairs with the 70o one from the other eye, while the 30o grating repairs with the remaining 100o grating) moving at different directions from the original monocular 30o plaids. This reduces the total perceived motion. Our findings reveal the presence of inherent rules in global motion perception that can even shatter monocular image integrity.

43.405 **Translational pattern discovery: evidence of a two-stage global-local strategy** Tom Collins[1](tomthecollins@gmail.com), Joy Geng[2]; [1]Department of Computational Perception, Johannes Kepler University Linz, [2]Center for Mind and Brain, University of California, Davis

The discovery of repeated patterns (e.g., AABB in the string AABBCBCAABBCAABB) enables us to form compressed representations that reduce processing demands. We have developed a novel paradigm for investigating how the human visual system discovers spatial patterns (specifically, translated point collections). Stimuli consisted of approximately 35 gray points arranged on a 16x16 (hidden) grid (see PDF, Fig. 1). The display always contained 4 embedded point collections on 4x4 grids, some of which were translations. In a 6s discover phase, subjects identified point collections that occurred translated elsewhere in the display. The difficulty of identifying translations was manipulated by (1) adding random points or "noise" (low and high noise conditions with signal-to-noise ratio of 10 and 2 respectively) and (2) varying the distance between embeddings (low and high separation conditions with minimum 1 and 4 grid distance). Immediately following, subjects saw a point collection in a 4s decide phase, and responded whether or not that collection had occurred more than once in the previous discover phase (Figs. 2-3). A within-subject ANOVA on accuracy, with factors for noise and separation, revealed a significant main effect of noise ($F_{1,5}$ = 24.2, p <.01, see also Fig. 4). Eyetracking data suggested that in the low noise condition, subjects perceived the 4 embedded collections on a global scale first (Fig. 1, fixations 1-3). Next they checked for differences between pairs of embeddings on a local scale (Fig. 1, fixations 7-11), with tracks similar to visual comparison tasks (Pomplun et al., 2001; Galpin & Underwood, 2005). Often, global perception was impeded by high noise, leading to incorrect responses. An adapted pattern discovery algorithm (Meredith et al., 2002) had higher accuracy on this task than all but one subject. This is likely because the algorithm, which does not employ a global-local strategy, is less affected by noise.

43.406 **Contextual effects in human visual cortex depend on surface structure** Sung Jun Joo[1](sjjoo@uw.edu), Scott O. Murray[1]; [1]Department of Psychology, University of Washington

The neural response to a stimulus inside the receptive field of a V1 neuron ("target") is suppressed when it is surrounded by iso-oriented compared to orthogonal stimuli ("flankers"). Despite the importance of orientation-specific surround suppression in potentially mediating a number of important perceptual effects including saliency, contour integration, and orientation discrimination, the underlying neural mechanisms remain unknown. Here we show using measurements of event-related potentials (ERPs) in humans that surround suppression depends on the surface structure in an image. In Experiment 1, we established the basic surround suppression effect using stimulus configurations where the target was surrounded by "nearby" flankers. P1 amplitude in our ERP data was suppressed when the flankers matched the target orientation (same condition) compared to when the flankers were orthogonal to the target orientation (orthogonal condition). In Experiment 2, we increased the distance between the target and flankers by doubling the flanker-target distance used in Experiment 1. Perceptually, the stimuli now appeared to be 3 isolated stimuli rather than a single array of stimuli. We found no difference in P1 amplitude between the same and orthogonal conditions. In Experiment 3, we used the distant-flanker configuration of Experiment 2 but made the target and flankers appear to be grouped on a common surface that was distinct from the background. P1 amplitude was suppressed in the same condition compared to the orthogonal condition. In Experiment 4, we used the same spatial parameters of Experiment 1—where we observed strong surround suppression—but moved the flankers to different surfaces than the target. Although the flankers were displayed in the near proximity of the target, we found no evidence of surround suppression in the P1 amplitude. Our results demonstrate a surprising role of high-level, global processes in determining when contextual effects occur in early visual cortex.

43.407 **Surface Configuration Effect on Surround Modulation in Glass Patterns** Pei-Yin Chen[1](r00227105@ntu.edu.tw), Chien-Chung Chen[1,2]; [1]Department of Psychology, National Taiwan University, Taipei, Taiwan, [2]Neurobiology and Cognitive Science Center, National Taiwan University, Taipei, Taiwan

The percept of the global form of a Glass pattern can be modulated by the presence of a surround Glass pattern (Li &Chen, 2010, JOV). This modulation depends on the global structures of both the central target and the surround. Here, we investigated whether such modulation can be influenced by the 3D configuration of the stimuli. The stimuli contained a central target (2.5deg radius) and an annulus surround (2.3 deg width). Both the target and surround were either concentric, radial or spiral Glass patterns (0.01 dot density). The depth modulation were achieved by binocular disparity. There were six 3D configurations: The target and surround were (A) on the same frontoparallel plane; (B) on different frontoparallel planes; (C) on the same 45 deg slanted plane; (D) on different slanted plane (+/-45 deg); (E) on the same concave or convex surface; and (F) one on a concave surface while the other on a convex surface. The coherence thresholds of the central target Glass patterns were measured at 75% accuracy with a 2AFC paradigm with or without the presence of a surround Glass pattern. When they are on the same surface, the concentric surround suppressed the detection of a concentric target, the spiral surround suppressed the detection of both concentric and radial target, and the radial surround suppressed the radial target detection regardless whether the surface was frontoparallel, slanted concave or convex. Such surround modulation effect was reduced or abolished when the target and the surround were on different surfaces. The surround modulation occurred only when the target and surround were either coplanar or on the same concave/convex surface regardless the depth difference between the target and the surround. Our results show that the surround modulation in Glass patterns depends on surface assignment.

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43.408 **A comparison of hypocycloid perception produced by two different elemental constructions** Alexander Rose-Henig[1](ar5010a@american.edu), Arthur Shapiro[1]; [1]Department of Psychology and Center for Behavioral Neuroscience, American University, Washington D.C

A hypocycloid is a geometrical construction in which a smaller inner circle rolls inside the circumference of a larger outer circle. Many researchers (e.g., Galileo; Johansson; Cutting and Proffitt) have been interested in the perception hypocycloidal motion, in part, because the information provided by points on the inner circle's circumference (the local motion) does not always predict the inner circle's path (the global organization). To investigate the perceptual organization found in hypocycloid motion, we compare two novel stimulus constructions: In Construction 1 a hypocycloid percept emerges from the motion of several individual dots that oscillate in straight lines through the center of the outer circle; in Construction 2, a hypocycloid percept emerges when the dots follow circular paths. For both constructions the key element for producing the hypocycloid pattern is the adjustment of the relative temporal phase of each of the dots (e.g., for construction 1, a 0° dot moves left/right, a 90° dot moves up/down, etc; the perception of a hypocycloid arises when the timing of each dot is shifted so that their temporal phases match the angle of their paths' separation). Here we show how these constructions produce "illusions" that can serve as powerful tools to investigate interactions between color, motion, attention, and perceptual grouping. For instance, we show that the global hypocycloid pattern is robust enough to be maintained even when physical lines or circles accentuate the local path of each dot; however, relatively small changes in the relative temporal phase can disrupt the global perception. Also, because Constructions 1 and 2 produce rotating circles with different internal rotation patterns, combinations of the two Constructions lead to a bi-stable image, whose rotational characteristics can be altered when the observer shifts attention to different cues placed on the circular paths.

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43.409 **Common fate versus cast shadows as influences on perceived motion direction and depth** Marouane Ouhnana[1](marouane.ouhnana@mail.mcgill.ca), Frederick Kingdom[1]; [1]McGill Vision Research, McGill University

Aim: Manipulation of an object's cast shadow has been shown to alter the object's perceived depth and motion direction in both static and dynamic displays (Mamassian et al., 1998 Trends Cogn. Sci. 2:288–95). However the effect holds even if the cast shadow looks unrealistic, for example by deforming its shape. Our aim is to test the possibility that something other than 'shadowness' is driving the percept. Method: We employed a variant of the ball-in-box stimulus used by Kersten et al. (1994 Max-Planck-Institut fuer biologische Kybernetik, Technical Report no 6) in which a floating test sphere recedes diagonally into the background over a checkered surface. Instead of a shadow, we introduced a second sphere below the first and moved it either diagonally or horizontally in temporal synchrony with the test sphere. Result: The test sphere appeared to move either diagonally or to rise up in the frontal plane depending on the movement of the second sphere, similarly to the effect of a shadow. Conclusion: We suggest that the different percepts implicate a form of common fate. As both spheres move in synchrony, the visual system groups them as a unitary entity. The second sphere serves to disambiguate the motion of the floating sphere by locking its motion into one of two planes, a diagonal plane in which the two motion directions are the same, and a frontal plane in which they are different. This suggestion expands on the common fate principle and may be an example of the broader range of common fate phenomena that Wertheimer had in mind (Wagemans et al., 2012 Psychology Bulletin, 1172:1217).

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43.410 **Cooperative but not Competitive Relationship Drives Perceptual Grouping of Objects** Jun Yin[1](yinjun@zju.edu.cn), Xiang Huang[1], Rende Shui[1], Mowei Shen[1]; [1]Department of Psychology and Behavioral Sciences, Zhejiang University, Hangzhou, P.R.China

Perceptual grouping is of critical value in understanding the world since it uncovers visual structure at the perceptual stage. Its occurrence is classically associated with physical principles which contribute to catch physical structure. However, for some visual scenes social properties are key factors in shaping another side of the visual structure -- social structure. Thus, it is equally important to explore whether human can perceive objects as an organized group according to social cues. To explore this issue, in the current study two fundamental human relationships, cooperation and competition were considered, which were constructed by forward replaying human trajectories when two agents (predators) were doing cooperative and competitive chase for a common target. Each relationship was compared with its backward replay (the control condition), which has poor impression of the social relationship between two agents but provides appropriate controls for low-level differences. Measuring the grouping effect by its induced attentional consequences, we found: 1) in the cooperative relationship, the attention automatically spreads within the group constituted by two agents, such that the cued agent facilitates the response for the target appearing at the other agent, relative to the control condition; 2) while for the competitive relationship, the attentional effect on two interactive agents has no difference compared with the control condition wherein the two agents aren't perceptually grouped. Even though other alternatives were ruled out (i.e., smaller distance and higher speed), the null grouping effect still existed for competitive relationship. These results suggested that the cooperative but not the competitive relationship rooted in dynamic chase can drive perceptual grouping of objects. Further, these findings implicate that social information can get involved in visual cognition at an early stage.

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43.411 **The Effect of Grouping on Knock-out** Ronald A. Rensink[1](rensink@psych.ubc.ca), Emily S. Cramer[1]; [1]Depts of Psychology and Computer Science, University of British Columbia

Knock-out is a new form of visual masking, distinguished by robustness to temporal onset and considerable indifference to the visual appearance of the mask (Cramer & Rensink, VSS, 2012). Indeed, some localized masks are as effective as their larger-scale counterparts. We investigate here the extent to which knock-out is sensitive to grouping. As before, observers detected a change in an alternating display containing an array of line segments, one of which changed orientation by 45° on half the trials. The duration of each display was 60 ms and the inter-stimulus interval (ISI) was 420 ms. When a mask was present, it appeared at the location of each item for 100 ms during the ISI, with a stimulus onset asynchrony (SOA) of 220 ms. Twelve observers were tested for each type of mask. Masks varied along overall spatial extent, and ease with which their constituents could form separate groups. Results showed that knock-out depended on spatial extent: masks that were bounded (i.e., terminated before they reached the edge of the screen) had a greater effect than those that were unbounded (i.e., appeared to extend off-screen). Grouping was also important: if the elements of an extended mask could form a group that was was bounded, substantial impairment resulted. Interestingly, this impairment did not rely on the elements being in one-to-one correspondence with the targets: performance suffered even when mask elements did not overlap any targets. These results suggest that the masking responsible for knock-out involves at least two processes: one that acts locally, and one that involves larger-scale structures that are largely irrelevant if not part of the same "framework" or "region" of the scene. They also suggest that knock-out itself is a useful way to explore the nature of these larger-scale structures, and the kinds of grouping processes involved.

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43.412 **Competition Between Grouping Principles** Einat Rashal[1](einatrashal@gmail.com), Ruth Kimchi[1], Yaffa Yeshurun[1]; [1]Institute of Information Processing and Decision Making, Department of Psychology, University of Haifa

The perceived organization of elements in a display is affected by the strength of grouping rules available (e.g., Ben-Av & Sagi, 1995). A 'winner-take-all' approach predicts that only the dominant organization is represented, and hence, ultimately reaches conscious perception (e.g., Kubovy & van den Berg, 2008).We tested the hypothesis that in situations where more than one organization is possible in the display, multiple representations are constructed, and while one of them is chosen for conscious perception the others are suppressed. We used the primed matching paradigm in which the observers are exposed to a prime stimulus that is followed by a pair of test figures. The test pair can consist of identical or different figures, and the observer's task is to give a "same" or "different" response to that pair. "Same" responses are relatively faster and/or more accurate when the test stimuli are similar to the prime than when they are dissimilar to it (e.g., Beller, 1971). The prime consisted of a matrix of elements organized (e.g., into columns/rows) by two grouping rules (dominant: brightness/color similarity; non-dominant: shape similarity) that lead to either the same organization (no-competition condition), or to two different organizations (competition condition; e.g., columns by brightness and rows by shape). A neutral prime containing no apparent organization served as a control condition. In the competition condition test figures were similar to one or the other of the two possible organizations in the prime. By varying the duration of the prime we were able to examine the time-course of representations construction (e.g., Razpurker-Apfeld & Kimchi, 2007). The results show a reduction of priming effects for the dominant organization in the competition condition compared with the no-competition condition at the longest prime duration, suggesting that although the dominant cue dominates early organization, a competition seems to emerge later in time.

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43.413 **Conflating Kanizsa Figures with Perceptual Grouping?** Amy Kaplan[1](kaplanalain@gmail.com), Gideon Caplovitz[1]; [1]Department of Psychology, University of Nevada Reno

In recent years a number of papers have investigated mechanisms of 'perceptual grouping' using illusory figures, specifically Kanizsa figures, as stimuli. Here we take an historical perspective on the use and meaning of the term 'perceptual grouping' and contrast it with the use and meaning of other similar terms such as perceptual organization, visual organization and Gestalt formation that are sometimes used interchangeably. We found that the term perceptual grouping is most commonly applied to represent the processes by which individual elements are grouped into unified wholes, for example how a formation of flying geese are perceptually grouped to comprise the figure of a V. An important characteristic of a perceptual group is that the individual elements become parts of the grouped whole. In contrast, an important quality of Kanizsa figures is that the arrangement of inducer elements leads to the construction of a unified whole that is perceptually segmented from the elements themselves: i.e. the illusory figure is occluding the inducers. Indeed the emergence of the illusory figure is historically explained as a result of perceptual segmentation, such as figure-ground or local-global segmentation. Many contemporary papers investigating

Kanisza figures are in line with this explanation. As such we question the validity of using Kanizsa figures to study mechanisms of perceptual grouping and question some of the interpretations of data that conflate the two.

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43.414 The Global Precedence Effect and Differences in Political Temperament

Dillon Cornett[1](dilloncornett@gmail.com), Melissa Beck[1]; [1]Louisiana State University

Global visual information is generally perceived more readily than local information (Navon, 1977). This global precedence effect (GPE) is affected by attentional set in that it can be reduced with local priming and there are individual differences in the strength of the GPE. For example, people of collectivist religions show larger a GPE than people of individualist religions (Colzato et al, 2010). Individual differences have also been shown on attentional tasks for people of different political affiliations. For example, research using the gaze cuing task (Dodd, Hibbing, & Smith, 2011) and using appetitive and aversive pictures (Dodd et al., 2012) have reported differences between liberals and conservatives. Given that there appear to be differences in visual perception and attentional set for people of different political affiliations, the current study investigated possible differences in the GPE based on political temperament. Participants completed surveys about political affiliation from which they were categorized into one of three categories; Conservatives, Liberals, and Moderates. Participants were then presented with Navon stimuli in which the global and local letters were either congruent or incongruent and reported either the local or global letter. Consistent with the literature, the results from the current study show a GPE where observers were slower to respond and less accurate when asked to report the local level of the stimulus. However, the GPE was the same for Conservatives and Liberals. This suggests that individuals in the extreme ends of the political continuum have similar attentional allocation to global information over local information. Previously found differences between political groups may be due to the social or emotional nature of the stimuli presented in those studies. The results from the current study suggest that, in the absence of social or emotional stimuli, attentional allocation may not differ between liberals and conservatives.

43.415 How the global layout of the mask influences masking strength

Tandra Ghose[1](tandra@berkeley.edu), Frouke Hermens[2], Michael Herzog[3]; [1]Department of Psychology, University of Kaiserslautern, Germany, [2]School of Psychology, University of Aberdeen, U.K., [3]Laboratory of Psychophysics, Brain Mind Institute, EPFL, Switzerland

Visual masking is typically explained by local interactions between mask elements and the target. However, Hermens & Herzog (2007) showed that the global spatial layout of the mask, rather than its local structure, determines masking strength. Here we investigate how global aspects of luminance and timing influence masking strength. A vernier target was followed by a mask of 25 aligned verniers. Participants were asked to report the offset direction of the target vernier. Masking is weak when all mask elements are of the same length, luminance, and are displayed at the same time. When the two mask elements directly next to the vernier are longer, performance deteriorates dramatically. The same holds true if the elements are of higher or lower luminance or are displayed with a short delay. Masking energy cannot explain these local effects because higher and lower luminance elements increase masking. When every second mask element is longer, performance improves compared to when only the neighboring lines are longer- even though these elements are part of both conditions. Hence, the global mask layout, rather than some local aspects, determines masking strength. However, this does not hold true for luminance manipulations which seem to be determined by the directly neighboring lines. For temporal conditions, a complex non-monotonic pattern is found. Clearly, masking strength cannot be explained by simple models based on local interactions alone. We argue that these findings should be taken into account when masking is used as a tool to investigate visual perception.

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43.416 Emergent Features Help Resolve Ambiguous Apparent Motion

Anna Cragin[1](cragin@rice.edu), Belicia Ding[1], James Pomerantz[1]; [1]Department of Psychology, Rice University

A Pickler-Ternus display is an ambiguous apparent motion stimulus in which three disks are horizontally aligned, and the left disk disappears as a disk in the far right appears. This motion can be perceived in one of two ways: (1) left disk can be perceived as flipping to the right (element), or (2) all the disks are shifting together as a group to the right (group). When intervals between frames are short (as low as 0ms), element motion is more likely to be perceived. When frame intervals are long (100ms), however, group motion is more likely to be perceived. At intermediate intervals, the display is bistable: the nature of the motion is ambiguous because there are two solutions to the correspondence problem. Previous research has shown that it is possible to change the distinguishing surface features of the disks (e.g., color, texture) to bias the perception. In this experiment, we were interested in investigating bias towards element or group motion when the disks contain images with special perceptual features (Emergent Features, e.g. parallelism, intersections). Specifically, we investigated the role of Emergent Features in solving the correspondence problem via intra-stimulus grouping (the more differences in Emergent Features there were between the two images used for the display, the better people were at solving the correspondence problem) and inter-stimulus grouping (the more Emergent Features arising from the elements within a row that group them together, the more likely it was that they were seen moving as a group). We conclude that Emergent Features are important in perceiving motion as well as stationary forms during visual search.

43.417 False Pop Out and "Anti-metamers"

Kimberley Orsten[1](kdo@rice.edu), James Pomerantz[1]; [1]Department of Psychology, Rice University

False Pop Out (FPO) occurs when distractor items in a singleton search display pose as targets. The phenomenon is observed in response distributions in which there are a disproportionately large number of responses given to one particular distractor(s) (see Supplement). Such error distributions have been found in various display types: 3 in a row, 4 in a square, and patterns composed of heterogeneous items. These findings are consistent with the Theory of Basic Gestalts (Pomerantz & Portillo, 2011), as these patterns of performance seem to be the result of inter-item grouping in visual search displays. That is, emergent features within search displays guide participants' perceptions of the displays, resulting in consistent patterns of erroneous responding. Recent research has also searched for pure FPO, in which one distractor falsely receives all responses (see example of one such stimulus in Supplement). In this case, two identical items would look different from one another ("anti-metamers"), and with displays of three or more items (i.e., singleton displays) one of the homogeneous distractors would be incorrectly perceived as the target as much as 100% of the time.

43.418 Biases in human number estimation are well-described by clustering algorithms from computer vision

Hee Yeon Im[1](heeyeon.im@jhu.edu), Sheng-hua Zhong[2], Justin Halberda[1]; [1]Department of Psychological and Brain Sciences, Johns Hopkins University, [2]Department of Computing, Hong Kong Polytechnic University

When presented with visual scenes containing multiple items, humans can rapidly organize elements into groups and can estimate the number of items within groups. Here we systematically examine how humans define groups of items and how grouping influences numerical estimation of items. Through behavioral experiments and modeling work, we find that human estimates of groups and items are well-described by k-means clustering algorithm (Fig.1) that is widely used for image segmentation in computer vision. In Experiment 1, we asked subjects to estimate the number of clusters in images of randomly located dots presented for 50-300 msec. Estimates of the number of clusters were stable from as early as 50 msec, and highly consistent across individuals. Next, the model estimated the number of clusters for these same images with a single free parameter for center-to-center distance among items (i.e., clustering threshold). The best-fit clustering threshold was a distance of 4˚ (Fig. 2) - which is also seen as a critical distance for optimal spatial separation in object tracking tasks [1,2]. In Experiment 2, we asked a different set of subjects to estimate the number of individual dots (not clusters) in these same images. We found that subjects tended to underestimate the number of dots - especially when the image contained many clusters. Comparisons to the model estimates suggested that human subjects discount dots that fall within clusters and linear regression analyses revealed that clusters containing more items yielded more underestimation. Based on our findings, we propose a hierarchical model in which inputs from two interactive levels of representations of items and of clusters in an image together predict human performance on various numerosity tasks. Our work uses behavior and computer vision to begin to reveal how number can be rapidly estimated from brief visual scenes.

43.419 What makes people see patterns?

Bjorn Hubert-Wallander[1](bjornhw@uw.edu), Geoffrey M. Boynton[1]; [1]Department of Psychology, University of Washington

Why do some visual stimuli look "random" and others more like a pattern? Conventional wisdom suggests that repeating, alternating, or symmetrical arrangements of features play a role in the perception of a pattern, but this evidence is often subjective and anecdotal. We aimed to more precisely characterize the factors that lead to the perception of randomness and pattern-ness starting with a simple set of visual stimuli: five-element sequences of horizontal and vertical Gabor patches arranged in a vertical column. In our main experiment, we administered a two-alternative forced-choice task to subjects via Amazon's Mechanical Turk platform. On each trial, subjects chose which of two presented sequences appeared most random. Subjects made over 10,000 behavioral responses across all 496 possible pairings of the 32 possible sequences. We fit the results with a simple quantitative model that projects each sequence onto a single dimension that ranges from perceived randomness to perceived pattern-ness. We found that by using only a few objective, calculable descriptions of the stimuli, we could predict the subjects' choice data with extremely high accuracy and reliability. Specifically, we found that (1) low entropy, (2) a low probability of alternation, and (3) a lack of symmetry all contribute systematically to the likelihood that one stimulus will appear more like a pattern than another. In two further behavioral experiments, we then show that the model generalizes very well to both longer and more abstractly represented stimulus sequences. Since our model can predict the perceived randomness or pattern-ness of any binary sequence, we also demonstrate an interesting application: given a binary sequence with a subset of pre-specified elements, we can fill in the remaining elements to produce a sequence that will appear either maximally random or maximally patterned to a typical human observer.

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Development: Autism Spectrum Disorders

Monday, May 13, 8:30 am - 12:30 pm

Poster Session, Orchid Ballroom

43.420 Visual cortical architecture in high-functioning autism spectrum disorders

D. Samuel Schwarzkopf[1,2,3](s.schwarzkopf@ucl.ac.uk), Elaine J. Anderson[1,4], Benjamin de Haas[1,2], Sarah J. White[2], Geraint Rees[1,2]; [1]Wellcome Trust Centre for Neuroimaging, University College London, London UK, [2]Institute of Cognitive Neuroscience, University College London, London UK, [3]Cognitive Perceptual & Brain Sciences, University College London, London UK, [4]Institute of Ophthalmology, University College London, London UK

Previous research suggests enhanced local visual processing in individuals with autism spectrum disorders (ASD). Here we used population receptive field (pRF) analysis to test whether the fine-grained retinotopic architecture is atypical in individuals with high-functioning ASD (n=14) compared to neurotypical, demographically matched controls (n=12). We measured Blood Oxygenation Level Dependent (BOLD) responses using functional MRI while participants viewed traversing bar stimuli for retinotopic mapping. For each point in visual cortex we fitted a two-dimensional pRF model to the observed data that accounted both for excitatory and inhibitory effects on the BOLD response (Zuiderbaan et al., 2012, J.Vis. 12(3):10). Compared to controls, in the ASD group pRFs were larger in portions of extrastriate cortex representing the peri-foveal visual field. Further analyses showed that this was not due to differences in the shape of the hemodynamic response function or increased measurement noise. Interestingly, pRF sizes in ASD individuals also correlated with their autism quotient (AQ). In further experiments, outside the scanner, we tested the strength of the Ebbinghaus size illusion and the ability to discriminate orientation and global motion direction. ASD individuals were less able to tolerate directional uncertainty in global motion than controls but none of the behavioural measures were significantly related to the observed functional architecture of visual cortex. We propose that differences in pRF parameters may result from differential attentional deployment in ASD and this effect may be linked to the severity of behavioural symptoms in autism.

Acknowledgement: Wellcome Trust

43.421 The Functional Organization of the Ventral Visual Pathway in Adults with Autism

Alexander J E Kell[1](alexkell@mit.edu), Kami Koldewyn[1], Nancy G Kanwisher[1]; [1]McGovern Institute for Brain Research, MIT

People with Autism Spectrum Disorders (ASD) reportedly show deficits in biological motion perception, face memory, and visual attention. Do differences in the functional architecture of visual cortex underlie these putative behavioral differences in visual processing? Evidence to date is mixed. Here we used functional magnetic resonance imaging (fMRI) to determine whether functionally defined regions of the ventral visual pathway are different in volume or selectivity in adults with ASD compared to typical adults. We scanned adults with ASD and age-matched typical controls (TCs) while they viewed movies of faces, bodies, scenes, objects, and scrambled objects. Each ASD subject was individually matched to two TCs on temporal signal-to-noise ratio (tSNR). Category- and object-specific regions of the ventral pathway were functionally defined bilaterally in each subject individually, including: i) face selective regions (the fusiform face area, occipital face area, face-selective superior temporal sulcus), ii) place-selective regions (parahippocampal place area, retrosplenial complex, occipital place area (formerly known as transverse occiptal sulcus)), iii) the object-selective lateral occipital complex, and iv) body-selective extrastriate body area. Preliminary results (n ASD: 10; n TC: 20) show that adults with ASD have no significant differences in the volume of any category- or object-selective region. Findings to date suggest that the functional organization of the ventral visual pathway is unaffected in adults with ASD.

Acknowledgement: Ellison Medical Foundation and NIH grant EY13455

43.422 Neural Correlates of Congruency Sequence Effects in Autism Spectrum Disorders

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Persons with Autism Spectrum Disorder (ASD) often exhibit stereotyped, repetitive, instead of flexible and appropriate behavior for a particular goal and context. We investigated how adjustments of cognitive resources in ASD, a developmental disorder, may be influenced by recent experiences with stimuli that have either competing or complementary dimensions (i.e., influence of "trial history"; Gratton, 1992). Previous work has shown that experiencing stimuli features that are incompatible with an internal goal slows down performance on the current trial (thus producing "interference"), but facilitates processing on a subsequent conflict trial, as manifested in speeded RTs and increased accuracy (e.g., Botvinick et al., 2001). Functional MRI and behavioural data were acquired from children and adults with ASD (N=55) and typically developing controls (N=78), matched by age, IQ, and gender. Participants performed a stimulus-response compatibility task (Simon, 1969) by judging the direction of left- or right-facing arrow, while ignoring its spatial location. We found that ASD and TD participants responded more quickly to current congruent trials compared to incongruent trials ($F(1,131) = 124.419$, $p < 0.000$). In both groups RTs were faster on a current incongruent trial if a preceding trial was another incongruent trial, $F(1,131) = 77.386$, $p<0.000$, an effect called conflict adaptation. Dorsal Anterior Cingulate Cortex (dACC) and Left Inferior Frontal Gyrus (left IFG) activity was associated with processing of interference from incongruent dimension in both TD and ASD groups, with ASD showing significantly more DLPFC activity compared to TD group. However, only TD group showed context-specific conflict adaptation activation in DLPFC, mirroring the behavioural pattern. ASD's capability to suppress or inhibit prepotent responses is sustained by a network of associative cortices and sub-cortical regions. DLPFC activity was attenuated in ASD depending on previous trial conflict history, perhaps reflecting a decreased neural contribution of DLPFC to flexible processing in ASD.

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43.423 Neuropsychological differences between Asperger syndrome and high functioning autism

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The assumption that Asperger Syndrome (AS) and high functioning autism (HFA) are quantitative manifestations of the same disorder, proposed in the DSM-V to be published in 2013, today remains somewhat controversial. The purpose of this study was to examine possible differences between AS and HFA patients concerning visual cognitive function and behavior. Six AS patients (males, age range: 7-11 years old), 12 HFA patients (males, 6-12 years old) and 25 controls (males, 6-13 years old) were tested. Diagnosis was made by psychiatrists from the Psychiatric Institute of the University of São Paulo with basis on DSM-IV criteria. General intelligence was evaluated by the Raven Matrices Test. Cognitive performance was assessed with the Cambridge Neuropsychological Test Automated Battery (CANTAB), using tests of sustained visual attention (Rapid Visual Information Processing, RVP), short-term spatial memory (Spatial Recognition Memory, SRM), short and long-term visual memory (Pattern Recognition Memory, PRM), and visual memory for complex stimuli (Delayed Matching to Sample, DMS). The Child Behavior Checklist was used for behavioral evaluation. Intellectual scores were within the normal range among participants, and there were no significant differences between groups (Kruskal-Wallis ANOVA, $p>0.05$). HFA participants performed significantly worse than AS patients and controls on Pattern Recognition Memory long term recall, Spatial Span backwards, and Spatial Recognition Memory test ($p<0.05$). Compared to HFA patients and controls, AS patients showed elevated anxiety/depression scores on CBCL ($p<0.01$). AS and HFA patients presented distinct

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visual memory profiles. Higher anxiety/depression symptoms in the AS group may reflect self-consciousness of difficulty in sociability. This study supports the view that AS and HFS are qualitatively distinct disorders.

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43.424 **Atypical visio-temporal processing in Schizophrenia and Autism Spectrum Disorders revealed by the continuous Wagon Wheel Illusion**

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Mental disorders such as schizophrenia and autism spectrum disorders (ASD) are mainly characterized by psychosocial dysfunction, but atypical perception is one of their additional common features that can provide important insight into the underlying psychopathological mechanisms. The observed abnormality of temporal processing in these patient populations has been proposed to reflect altered patterns of neuronal oscillatory synchrony. Here, we use the continuous version of the Wagon Wheel Illusion (c-WWI, in which observers report illusory reversals of a continuous, periodically moving stimulus, possibly caused by an oscillatory motion sampling mechanism), as a non-invasive behavioral approach to explore psychopathological changes in perception-related oscillatory synchrony patterns. Thus far, we have collected data from 4 groups: schizophrenia (n = 11), schizophrenia controls (n = 11), ASDs (n = 6), and ASD-controls (n = 6). Each participant watched computer-generated wheels (12 cycles of a sinusoidally modulated luminance pattern, 100% contrast) continuously rotating clockwise (or counter-clockwise) for 60 sec at the center of a CRT monitor (144 Hz refresh rate to minimize temporal framing artifacts); they continuously reported the perceived rotation direction. The c-WWI magnitude was measured as the relative duration of illusory motion perception. Temporal rotation frequencies were pseudorandomly selected from 2, 7, 10, 13, 16, 19, 21 Hz (4 trials each), and the actual rotation direction was randomized across trials. A 2-way ANOVA with factors “frequencies” and “group” (patients vs. controls) revealed a marginal interaction effect for the schizophrenia group ($F_{7,140}$ = 1.82, p = .17; c-WWI peaked at higher temporal frequencies in patients) and a significant interaction effect for the autism group ($F_{7,70}$ = 3.7, p <.05; c-WWI peaked at lower temporal frequencies in patients). Our preliminary results suggest that the c-WWI could be a powerful tool to non-invasively probe the relationship between temporal processing and neuronal oscillations in mental disorders.

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43.425 **Atypical Lateral Interactions in Autism**

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Atypical perception is regarded as a hallmark characteristic of Autism Spectrum Conditions (ASC), but its neural underpinnings are unknown. Building on our previous results deficits in coherent motion processing in ASC, we conducted two psychophysical studies probing the nature of lateral interactions in ASC. First, we investigated the sharpness of the spatial and temporal gradients of attention. In 42 adult participants (21 ASC) we varied the spatial (2.46-6.56°) and temporal (67-210 ms) offset of an exogenous cue relative to a subsequent target stimulus. In both groups, performance decreased with increasing target distance from the cue, reflecting the spatial gradient of attention (p<0.001). Critically, this gradient was steeper in individuals with ASC (p<0.009) and tended to evolve more rapidly in time. Further, the slope of the spatial gradient predicted autistic symptoms/traits in both ASC and control groups (p<0.017). This sharper gradient may reflect increased lateral interactions in early visual processing in ASC. Second, we investigated binocular rivalry, which reflects competitive interactions in visual cortex. In 39 adult participants (21 ASC) two images were presented on the horizontal meridian of a screen, each within a tinted square (red/green, width: 1.75°). A mirror stereoscope reflected the images into the participants’ left/right eyes. Participants were instructed to continuously report their perceived image (red, green, or ambiguous). Individuals with ASC displayed a slower rate of binocular rivalry (p<0.016), longer ambiguous percepts (p<0.014), and a stronger tendency to revert to a previously perceived percept (p<0.022). Both rivalry rate and ambiguous percept durations strongly predicted autistic symptomatology (p<0.016). This reduction in binocular rivalry may reflect disrupted excitatory/inhibitory balance in ASC. Together, the sharper gradient of spatial attention and slower dynamics of binocular rivalry provide potential insight into the perturbations of neural circuitry that may underlie both perceptual and cognitive levels of autistic symptomatology.

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43.426 **Assessing lateral interactions within the early visual areas of adults with autism.**

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Background. Although atypical performance on visuo-spatial tasks targeting early, non-social perception is a defining characteristic of autism, few biologically plausible hypotheses are available to explain them. Some authors have theorized that persons with autism may have atypical local connectivity resulting in altered response properties of early visual feature detectors. The goal of this study is to use steady-state visual evoked potentials (ssVEPs) to measure and define local neural activity originating from lateral interactions between neurons within early visual areas elicited by windmill-dartboard stimuli (Zemon & Ratcliff, 1982). Methods. Eight participants with autism and 9 typically developing participants, matched for full-scale IQ and age (18-30 years), were asked to passively view the windmill-dartboard stimuli while ssVEPs from four electrodes over the occipital cortex (Oz, POz, O1 and O2) were collected. Windmill-dartboard stimuli consisted of a radial pattern comprised of concentric contrast reversing zones with contiguous static zones. EEGs were analyzed using a Fast Fourier Transform. First- and second-harmonic components of the steady-state responses were used to calculate indices reflecting facilitatory (FI) and inhibitory (SI) cortical interactions, which were compared between groups. Results. Preliminary results demonstrate that there are no group-differences for either FI or SI cortical interactions. Conclusions. To date, our results suggest that cortical lateral connections within early visual brain areas whether defined by facilitatory (FI) and inhibitory (SI) indices, are similar in autism and control participants. However, given the small sample size, we have yet to draw a strong conclusion from the results; data collection (and analysis) is ongoing. In a complimentary study, we are also presently analyzing ssVEP data collected for the same group of participants while viewing low-contrast Gabor patches presented ether in isolation (target), or flanked by collinear/orthogonal Gabors at different contrasts (8, 16, 30%) at target-flanker distances (1.5λ, 3 λ, 6 λ).

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43.427 **Development of Kanizsa Illusory Contour perception in Autism Spectrum Disorder**

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Goal. Autism spectrum disorders (ASD) are neurodevelopmental disorders characterized by deficits in social and communication skills, and repetitive behaviors. Sensory perception is reportedly atypical in ASD, marked by poor global form processing. Previous studies have found impaired performance on a variety of global processing tasks in ASD, but results are inconsistent. We employed an objective task with limited verbal instructions to assess global form processing in ASD. Methods. We used shape match-to-sample task in which participants saw a real – bounded – form followed by a pair of Kanizsa Illusory Contours (KIC) (subjective shapes induced from local “pacman” elements); their task was to indicate which KIC shape matched the previously displayed real sample shape. The stimuli were presented on a touch-sensitive display; eye position was monitored throughout. Non-contingent positive feedback was provided to maintain motivation. We compared performance across three populations: those with a confirmed diagnosis of ASD, those with a diagnosis of Attention Deficit-Hyperactivity Disorder (ADHD), and typically developing children (NT). Participant age ranged from 4 years to adulthood. Results. 22 participants (13 ASD, 4 ADHD, and 5 NT) completed testing. Accuracy increased with age within all three groups, with 5-6 year-olds performing below criterion (80% correct) and all groups reaching plateau by 10-13 years. Performance of the ADHD and NT groups was superior to the ASD group prior to age 10 years. The youngest children were more likely to touch the pacmen than the center, suggesting a local perceptual strategy, rather than the global strategy of older children. ASD children were less likely to touch the center than the other groups before age 10. Response time decreased similarly with age in all groups. Conclusion. These results demonstrate a fundamental change in perceptual ability between early and late childhood in ADHD and typical controls, which is delayed in individuals with ASD.

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43.428 **Visual Scanning Patterns During Facial Identity and Emotion Processing in Typically Developing Individuals and those along the Autism Spectrum**

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Our patterns of eye movements are influenced by task demands (Chen & Zelinsky, 2006). Malcolm et al. (2008) reported preferential scanning of the upper and lower face for information about identity and emotion, respectively. However, their data. were based on scanning of faces displaying only two emotions: happiness and disgust. Both of these emotions are predominantly expressed using the lower half of the face. We sought to determine whether Malcolm et al.'s conclusions would extend to the perception of more emotions. Additionally, we investigated whether adults with autism spectrum disorder (ASD), a clinical population with known face processing difficulties, showed similar eye movement preferences to those of matched controls. One set of stimuli was used comprising faces that expressed anger, disgust, fear, happiness, neutrality, sadness, and surprise while young adults made identity and emotion judgments. Eye-tracking, reaction time, and accuracy data were collected. Participants made more upper- than lower-face fixations for both the emotion and identity tasks. Like Malcolm et al (2008), the proportion of upper- to lower-face fixations was greater for the identity than the emotion task for all emotions. Relative reliance on the upper and lower regions of the face varied with emotion, regardless of the task. Participants with ASD scanned more differently during the emotion than the identity task. They fixated less often overall, yet still showed a general trend to fixate the upper more than the lower face. However, this pattern varied to a greater extent with face emotion than in typically developing participants, with some emotions revealing no preference for the upper or lower face. Results of this experiment confirm the presence of top-down, task-driven effects on the visual scanning of faces, effects that depend on facial emotion and that are altered in individuals with ASD.

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43.429 **High Autism Spectrum Individuals Use Configural Information More than Neurotypical Individuals When Recognizing Faces**

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Individuals with Autism Spectrum Disorder (ASD) show impaired recognition of faces and facial expressions. Face recognition deficits are believed to result from a lack of (or dysfunction in) configural/holistic processing mechanism and a shift toward feature-based recognition strategies. The current study addressed this deficit using a two-part experiment that independently measures face perception and face recognition strategy (Schwartz & Chang, 2008). In Part 1 of the experiment, we measured face discrimination thresholds for seven internal face dimensions (i.e. eye shape, nose-mouth distance, etc) using a same-different task. Face stimuli were caucasian and were displayed in grayscale, and an adaptive thresholding procedure (QUEST) was used. In Part 2 of the experiment, we measured face recognition strategy using a 3-alternative forced error (3-AFE) design, a modified 3-AFC, delayed match-to-sample task in which there is no correct answer. Distractors were calibrated using thresholds measured in Part 1 and each distractor varied in only one dimension from the target so participant response indicated the dimension with the least utility. Participants were grouped according to degree of autistic symptomatology using the AQ-50. Participants scoring 2 standard deviations above and below norms were placed into High AQ and Low AQ groups, respectively. High AQ individuals showed lower discrimination threshold for eye shape, nose shape, eye-eye distance, eye-nose distance, and nose-mouth distance (five of the seven dimensions manipulated). These results suggest that high ASD individuals are significantly more sensitive to differences in those dimensions. When recognizing a target face from a set of distractors, High AQ individuals used eye-nose distance and nose-mouth distance more than Low AQ individuals, but used eye shape and eyebrow shape less than Low AQ controls. These results suggest high ASD individuals will outperform neurotypical observers when recognizing faces in which nose- and mouth-related distances are diagnostic of identity or facial expression.

43.430 **Low- and high-level vision in individuals with autism spectrum disorder**

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Autism Spectrum Disorder (ASD) is often associated with impaired performance in high-level visual tasks such as recognition of faces or facial expressions. In contrast, individuals with ASD may outperform neurotypical controls in detail-oriented visual tasks. We investigated whether this superior ability for fine detail in ASD originates from fundamentally superior low-level processing of spatial frequency and orientation. We tested 19 adult participants, 13 controls and 6 with ASD in two low-level and three high-level visual tasks. In Experiment 1, we measured contrast thresholds for detecting Gabor patches ranging in spatial frequency between 0.5-16cpd. Control results replicated typical contrast sensitivity profiles. ASD participants either showed atypical and reduced contrast sensitivity compared to controls (N=4), or showed typical profiles with higher sensitivity than controls at high spatial frequencies (N=2). In Experiment 2, we measured orientation discrimination thresholds for a 4cpd Gabor patch across base orientations ranging between 0-180 degrees. Controls again yielded typical curves associated with the oblique effect showing better discrimination around vertical and horizontal compared to oblique angles. Alternatively, ASD participants either showed a flat elevated threshold profile (N=3) or an impaired oblique effect (N=3). In Experiment 3, we measured contrast thresholds for face and house recognition. ASD participants were impaired in both tasks compared to controls. Moreover, the ASD group performed better with houses than faces whereas controls showed an opposite trend. Finally, in Experiment 4, we measured discrimination thresholds for subtle changes in facial expression. ASD participants showed significantly impaired performance compared to controls. Overall, our results confirm that high-level visual ability is impacted in people with ASD. In addition, these results suggest significant variation in visual abilities across the ASD population. While some may be impaired in both low and high-level tasks, others may show typical or superior low-level vision despite higher-level impairments.

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43.431 **Abnormality in face scanning by children with Autism Spectrum Disorder is limited to the eye region: Evidence from multi-method analyses of eye tracking**

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There has been considerable controversy regarding whether children with autism spectrum disorder (ASD) and typically developing children (TD) show different eye movement patterns when processing faces. We investigated ASD and age- and IQ-matched TD children's fixations and scanning of faces using a novel multi-method approach inclusive of the traditional AOI approach, a data-driven analysis, and a saccade path analysis. We found that ASD children spent less time looking at the whole face generally. After controlling for this difference, ASD children's fixations of the other face parts, except for the eye region, and their scanning paths between face parts were comparable either to the age-matched or IQ-matched TD groups. In contrast, in the eye region, ASD children's scanning differed significantly from that of both TD groups in a highly specific manner. First, ASD children fixated significantly less on the right eye than both TD groups. Second, unlike both TD groups, ASD children's fixations were more biased towards the left eye region. Third, their fixations to the left eye region were different from those of both TD groups: Whereas TD children fixated on the pupil region of the eye, ASD children fixated below the left eye as though they were trying to avoid direct eye contact. We conclude that ASD children do not have a general and pervasive abnormality in face scanning. Rather, their abnormality is limited only to the eye region, likely due to their strong tendency to avoid eye contact. This abnormality may be partially responsible for ASD children's significantly poorer face recognition performance than TD children.

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43.432 **Don't look at the face – social inhibition task reveals latent avoidance of social stimuli in gaze orientation in subjects with high Autism Quotient scores.**

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Background. Autism-spectrum characteristics are often obscured by rehearsed cognitive compensation strategies. We aim to devise tasks that avoid triggering compensatory behaviors, so that latent differences can be revealed. For example, the tendency for high-AQ subjects to avoid looking at eyes could be more reliably measured when subjects were occupied by an "orthogonal" task to avoid looking at the mouth (Shimojo et al., VSS 2012). Here, we test another method: use a task that challenges the pro-social impulses in low-AQ subjects, giving high-AQ subjects the advantage. We ask subjects to avoid looking at face stimuli. Method. Unscreened student participants (N=11; AQ 11-46; one diagnosed AS) viewed a series of paired face and flower images (FaceGen / photo) while their gaze was monitored (Eyelink2). The image pairs were arranged diagonally upper-right to lower-left, to minimize generic spatial biases in viewing. Subjects inspected the images under three task conditions: 1) Don't look at the flower, 2) Don't look at the face, 3) Free view. Later, they filled out the Baron-Cohen Autism Quotient (AQ) questionnaire. Each condition was assigned to a separate block of 36 trials, randomly ordered within subject. Results. Percentage of initial gaze shifts in the direction of the face was inversely correlated with the AQ scores in the "Don't look face" and the "Free view" ($p<.001;p<.05$), but not in the "Don't look flower" conditions. The "Don't look face" revealed a clearer and steeper slope of correlation. ANOVA revealed a main effect of task ($P<.001$), and an interaction between task and AQ category (high/low) ($P<.05$). Discussion. People with low AQ scores showed difficulty suppressing a tendency to look at eyes and faces. As AQ scores increase, this difficulty declines. This reversed diagnostic strategy may aid the design of simple measures, to complement the existing methods based on complex social tasks.

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43.433 **Gaze-oriented Attention in fearful and happy facial expressions varies with autistic traits**

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Gaze is an important social signal used to determine others' intentions. Previous gaze-cuing studies have shown faster responses to gazed-at targets than to non-gazed-at targets. This gaze orienting effect (GOE) reflects the spontaneous orientation of attention toward gaze direction, and is negatively correlated with the autism quotient (AQ) score indexing autistic traits in the general population. Thus, in accordance with clinical observations of autistic individuals, participants with many autistic traits seem to show a weaker gaze following than those with little autistic traits. Recent studies have also shown that attention orienting by gaze is modulated by the expression of the face cue. It remains unknown, however, whether this emotional effect varies as a function of autistic traits. The present ERP study investigated whether autistic traits impact the modulation of the GOE by fearful and happy emotions. Two groups were tested, one group with low AQ scores (<18, less autistic traits) and the other with high AQ scores (>26, more autistic traits). Stimuli consisted of centrally presented neutral faces dynamically averting their gaze to the side before expressing fear or happiness. Participants localized the subsequently presented target as fast as possible while maintaining their gaze centered. The GOE was modulated by emotions only in the high AQ group due to a decreased GOE for happy compared to fearful faces. While responses to fearful faces were similar in both groups, the GOE for happy faces was smaller in individuals with high compared to low AQ. In addition, ERP amplitudes to the target (P1 component) showed a gaze congruency effect in the low but not in the high AQ group indicating group differences in the neural processes involved in gaze-oriented attention. The results suggest a diminished sensitivity to social signals such as happy faces and gaze in individuals with many autistic traits.

43.434 **Embedded Figures Performance is Modulated by an 'Analytical Tendencies' Factor within the Systemizing Trait of Autism**

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The systemizing trait of autism (Wheelwright et al., 2006) has recently been found to contain a two-factor structure that differentially predicts a shift from reliance on global to local contextual cues, with an 'analytical tendencies' factor associated with decreased susceptibility to global cues and an 'insistence on sameness' factor associated with increased susceptibility to local cues (Reed & Dassonville, VSS 2012). Sensitivity to contextual visual cues has also been suggested to modulate performance in complex visual search tasks, such as in the Embedded Figures Test (EFT). In the EFT, an observer searches for a target object embedded in the gestalt of an extraneous contextual array. Studies have reported that individuals with autism spectrum disorders (ASD) exhibit superior performance on this task (Jolliffe & Baron-Cohen, 1997). It is unclear, however, whether this enhanced performance can be attributed to cognitive drives associated with a heightened processing of the local target, attenuated processing of the global context of the array, or some combination of the two. To test this, we compared performance on the EFT to scores from the general population on the two factors of the Systemizing Quotient – Revised ('analytical tendencies' and 'insistence on sameness'). While scores on the 'insistence on sameness' factor were not predictive of performance, higher scores on the 'analytical tendencies' factor were significantly associated with superior EFT performance. These results suggest that heightened analytical tendencies can facilitate target disembedding in complex visual search tasks, likely through attenuated interference from the global context of the search array.

43.435 **Core and Extended Face-Processing Regions are Hypoactive in Autism and Related to Symptom Severity**

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Evidence suggests that individuals with autism exhibit hypoactivation in core face processing regions, including in the fusiform gyrus (FG), the occipital face area (OFA), and the posterior superior temporal sulcus (STS), and this hypoactivation is evident even in early adolescence (Scherf et al., 2010). In 20 high-functioning adolescents with autism (HFA) and 12 typically developing (TD) age, gender, and FSIQ-matched controls, we explored the possibility that there may be additional alterations in activation within extended regions of the face-processing network, including the VMPFC, amygdala, posterior cingulate (PC), and anterior temporal pole. We also evaluated the extent to which hypoactivation in face-related regions is related to the magnitude of autism-like symptoms, as measured with the Social Responsiveness Scale. Participants performed a 1-back task during the fMRI localizer, which included blocks of fearful faces, neutral faces, common objects, novel objects, vehicles, houses, and scrambled images. When analyzed in a group model, the TD adolescents exhibited strong face-related activation in both core (FFA, OFA, STS) and extended (anterior temporal pole, VMPFC, amygdala, PC) regions that was somewhat right lateralized. Interestingly, the HFA adolescents exhibited bilateral FFA activation; however, it was smaller in extent than in the TD adolescents, particularly in the right hemisphere. There was a dramatic reduction, and often a complete absence of activation, in the other core regions (OFA, STS) as well as in all of the extended regions. Furthermore, this hypoactivation was correlated with the severity of autism symptoms. Specifically, HFA individuals with more severe symptoms exhibited lower magnitude face-related, but not object-related, activation in the right FG and OFA. This correlation was absent in the TD adolescents. These findings indicate that the extent of atypicality in the functional organization of neural regions supporting face processing in autism is much broader than previously reported and is related to symptom severity.

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43.436 **Gender aftereffects in adults with autism spectrum disorder**

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Faces convey information that is crucial for social interactions, including identity, emotion and gender. Facial aftereffects have been used to explore the face categories, the psychological relationship among categories, and whether they are coded with the same, different, or overlapping neural networks. For example, adapting to distorted (e.g., contracted facial features) male faces will shift perception of subsequently viewed male faces in the

direction of the distortion (i.e., contracted male faces will be perceived as more normal looking), known as a simple aftereffect. If female faces are encoded with an overlapping neural network, then an aftereffect will also be evident when female faces are used during testing. Previous research has shown just that: in typical individuals, adapting to distorted faces from one gender will create aftereffects for faces of both genders, so male and female faces are coded with overlapping networks. In the current study we examined whether adults with autism spectrum disorder (ASD) show aftereffects when faces of one gender are used during training, and faces of the opposite gender are used during test. This would be evidence of overlapping neural representation of the two genders. Nineteen adults with ASD and 16 controls rated faces that ranged from extremely contracted to extremely expanded before and after being adapting to contracted or expanded faces from a single gender. Aftereffects were measured for each gender by calculating the change in distortion level rated most normal before and after adaptation. Consistent with previous work, typical individuals showed cross-gender aftereffects. Adults with ASD showed similar cross-gender aftereffects, suggesting that for this population, overlapping neural networks encode male and female faces . With these results we can rule out the possibility that male and female faces are represented entirely separately in ASD.

43.437 **Exploring the pattern of other-race effect in autistic and typically developing children** Liang-Hui Wang[1,2](wlhui0815@gmail.com), Sarina Hui-Lin Chien[1], Tzu-Yun Chen[2], Hsin-Shui Chen[2,3]; [1]Graduate Institute of Neural and Cognitive Sciences, China Medical University, [2]Department of Physical Medicine & Rehabilitation, China Medical University Bei-Gang Hospital, [3]Department of Physical Medicine & Rehabilitation, China Medical University

Background: The other-race effect (ORE) is a widely known observation that we can recognize own-race faces better than other-race faces (Meissner & Brigham, 2001). The face processing deficit in autism spectrum disorder (ASD) is broadly studied; however, the aspect regarding race sensitivity in autistic children's face processing is relatively unexplored. The present study aims to explore the pattern of other-race effect in children with autism spectrum disorder and typically developing (TD) match group. Methods: 18 ASD (mean age = 7.5 yrs) and 13 TD age-matched children (mean age = 7.6 yrs) participated the study. The face stimuli contained female faces of three races (Asian, Caucasian, African) and each with four levels of difficulty: Easy (change identity), Medium (change component: replaced eyes), Hard-eye (change configuration: widen eye spacing), and Hard-mouth (change configuration: moved up mouth). The visual paired-comparison old/new face task with two-alternative-forced-choice (2AFC) procedure was adopted. There were a total of 72 trials. 5 ASD children were excluded due to their inability to complete the experiment. Results: In the TD group, we found that the accuracy decreased and response time increased as the stimulus difficulty increased for each race. They also showed a moderate own-race advantage that the best performances (highest accuracy and lowest RT) were found in the Asian face across conditions. This finding was consistent with our previous adult studies. In the ASD group, however, we did not find an own-race advantage for the Asian faces at all. In addition, contrary to TD group, the highest error occurred in the Hard-eye condition rather than the Hard-mouth condition. The performance for the Medium condition was also significantly lower than that of the TD group, indicating a deficit in processing eye feature. In sum, our findings suggest that ASD children did not exhibit own race advantage.

Acknowledgement: This study was supported by the National Science Council of Taiwan Grant #99-2410-H-039-003-MY3 to Dr. S. H. L. Chien

43.438 **Stimulus-driven visual attention engages subcortical visual areas in typical development but not autism** Vanessa Troiani[1,3](troiani@mail.med.upenn.edu), Robert Schultz[2,3]; [1]Department of Neuroscience, School of Medicine, University of Pennsylvania, [2]Department of Psychiatry & Pediatrics, School of Medicine, University of Pennsylvania, [3]Center for Autism Research, Children's Hospital of Philadelphia

Relevant stimuli efficiently engage attention, potentially due to engagement of the amygdala and enhanced processing in regions involved in visual salience. Based on the differential motivational-relevance of fearful faces, we hypothesized that a stimulus-driven motivational signal in the amygdala may increase connectivity with regions involved in processing visual salience. Furthermore, we examined whether a failure to engage this system contributes to impaired amygdala-guided attention in autism. To test this, we used a novel fMRI paradigm combining continuous flash suppression and an orthogonal letter-detection task to suppress fearful face and house stimuli from conscious awareness for the duration of an fMRI session. In a whole-brain analysis with 29 typically developing children, we find activation of the superior colliculus, thalamus, amygdala, and hippocampus in response to suppressed images (both faces and houses) compared to a no-stimulus control. Activations in these subcortical regions were not accompanied by changes in higher-level visual regions associated with processing faces and houses in conscious vision: We found no differentiation of the stimulus categories in the fusiform face area and parahippocampal place area using either mean responses or multi-voxel patterns, indicating that object-level information was successfully suppressed from higher-level visual cortices. In a connectivity analysis using regions of interest from our previous work, we find a category-specific (fearful faces > houses) increase in amygdala connectivity with the right pulvinar and left inferior parietal cortex, regions involved in processing visual salience. In conclusion, typical development is associated with activation of the amygdala in response to objects presented outside of conscious awareness and differentiation between objects based on an amygdala connectivity profile. We find no activation of the amygdala or other subcortical regions in response to suppressed stimuli in 32 children with autism, which indicates impaired stimulus-driven attention and a disturbance of adaptive processing of visual categories even prior to awareness.

43.439 **Audiovisual temporal integration in Autism Spectrum Disorder** Paula Regener[1](p.regener.1@research.gla.ac.uk), Scott Love[2], Karin Petrini[3], David Simmons[1], Frank Pollick[1]; [1]School of Psychology, University of Glasgow, [2]Department of Psychological & Brain Sciences, Indiana University, [3]Institute of Ophthalmology, University College London, London

The ability to integrate auditory and visual information is a crucial part of everyday life. The Temporal Integration Window (TIW) provides a measure of how much asynchrony can be tolerated between auditory and visual streams before one loses the perception of a unitary audiovisual event. Previous investigations of the TIW in individuals with Autism Spectrum Disorders (ASD) show mixed results in how performance compares to typically developed (TD) individuals. The current study looked at the TIW across a range of audiovisual stimuli types to further examine this issue. This range of stimuli included the following audiovisual pairings: 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). Seven adult males with ASD, and their age, sex and IQ matches were shown the three audiovisual stimuli with varying degrees of audiovisual asynchrony. These levels of asynchrony included presenting the auditory information either before or after the visual information by 333, 267, 200, 133 and 67 ms. In separate blocks participants were asked to make either Temporal Order Judgements (TOJ) or Synchrony Judgements (SJ) when presented with these stimuli. For both TOJ and SJ judgments psychophysical fits to the data provided estimates of the Point of Subjective Synchrony (PSS) and the width of the TIW. We ran ANOVAs on the estimates of PSS and TIW width using within factors of judgement (SJ, TOJ) and stimulus (BF, PLD, FV), and a between factor of group (ASD, TD). No significant effects were found for PSS. Results for TIW width revealed a main effect of judgement (wider TIW for TOJ than SJ) as well as a main effect of group (wider TIW for ASD than TD).

Face perception: Social cognition

Monday, May 13, 8:30 am - 12:30 pm

Poster Session, Orchid Ballroom

43.440 **Culture shapes interbrain synchronization during human goal decoding** Luca Vizioli[1](luca.vizioli@unifr.ch), Junpeng Lao[1], Helen Rodger [1], Roberto Caldara[1]; [1]Department of Psychology, University of Fribourg, Switzerland

Human societies are built on people accomplishing balanced individualistic and collectivistic goals to enhance their survival. Culture impacts upon human interactions and plays a critical role in regulating social goals. Western societies are individualistic, promoting values of independence, individual goals and rights. On the contrary, Eastern societies are collectivistic, promoting values of interdependence, group goals and duties. This marked social contrast was asserted as being responsible for consistent behavioral perceptual biases observed across cultures. However, whether culture has the potency to modulate natural human goal decoding in the brain has never been directly investigated.To this end, we used fMRI to record BOLD signals of Western and Eastern observers while they were viewing two natural movies featuring individualistic (i.e. eating alone) or collectivistic actions (i.e. a group building a house) in an African tribe. Movies were thus controlled for visual familiarity, culture and eye movements, which were locked to a central fixation. Inter-subject cortical synchronization was calculated by iteratively correlating the whole BOLD signal time course across all pairs of subjects, independently per voxel, movie type

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and cultural group. The resulting maps were normalised. Then, a BOLD collectivistic and individualist index was calculated, thresholded for each voxel by using bootstrap confidence intervals and averaged across movie type. Crucially, Western observers showed more synchronous activity in the occipital cortex during the decoding of human individualistic activities. The superior parietal lobe is involved in mapping internal representations of both the world and one's own body, and was found synchronously activated in Easterners during the decoding of the collectivist movies. Our data show culture-specific neural tunings for natural human individualistic and collectivistic goal decoding. These findings have profound implications in the understanding of social interactions and challenge the view that decoding of the visual world is universally achieved across human beings.

Acknowledgement: This study was supported by the Swiss National Science Foundation (100014_138627).

43.441 **Regional Differences in the Effects of Makeup on Attractiveness** Amanda C. Killian[1](amandakillian@csu.fullerton.edu), Jessie J. Peissig[1]; [1]California State University, Fullerton

We attribute positive and negative qualities to those who we perceive as either attractive or unattractive (Symons, 1979), and for many women attractiveness is enhanced with makeup and is commonly applied to the eye and mouth regions of the face. In past studies, increased luminance contrast in these regions has been found to increase attractiveness for females (Russell, 2009), supporting the idea that makeup increases attractiveness due its ability to increase the contrast differences between the eyes and lips and the rest of the face. However, prior research has not explored whether any increase in contrast in these regions will increase attractiveness, or if the effects are localized to specific sub-areas. In this study we examined additional regions of increasing luminance contrast in female faces using the application of cosmetics. Specifically, we compared increased contrast in the mouth region, above the eye region, and below the eye region to see if the effect differed depending on where the makeup was placed. Thirty participants judged the attractiveness of a large set of faces in which makeup was added to the upper eye region, directly under the eyes, and the lips. The data showed that makeup application does affect female attractiveness ratings perceived by others. Interestingly, the placement of the increased contrast was critical. In all conditions in which makeup was applied under the eyes, attractiveness ratings were significantly lower than for faces with no makeup. Similarly, makeup placement to just the lips led to significantly lower attractiveness ratings. In contrast, if makeup was applied on the upper eye region attractiveness ratings were significantly higher. These results suggest that general increased contrast in the eye or mouth region in females does not enhance attractiveness. Rather, the regional placement of the contrast increase may lead to either increases or decreases in perceived attractiveness.

Acknowledgement: California State University Fullerton Faculty/Student Creative Activity Grant: Attractiveness Judgments

43.442 **The Cheerleader Effect: Hierarchical Encoding of Individuals In Groups** Drew Walker[1](dehoffma@ucsd.edu), Edward Vul[1]; [1]University of California, San Diego

We demonstrate that ensemble coding in the visual system works conjointly with other cognitive mechanisms to produce the "the cheerleader effect," the pop-culture notion that individuals are more attractive when they are in a group. We propose that this effect arises because (1) the visual system automatically computes ensemble representations of faces presented in groups (Haberman & Whitney, 2009), (2) averaged faces are perceived as attractive (Langlois & Roggman, 1990), and (3) individual items are drawn to the ensemble average (Brady & Alvarez, 2010). Together, these results suggest that individual faces in a group will be biased toward a group average, and that group average tends to be more attractive than the individual faces, on average. To test this, we found 100 images of groups of three females (experiment 1) and males (experiment 2) on the internet and cropped them to show the three individuals together, or the same three individuals alone. Participants rated the attractiveness of these 300 faces, once presented in a group, and once presented individually. Consistent with the "Cheerleader Effect," female and male faces were rated as more attractive when they were presented with other faces then when they were presented alone (Expt 1: $t(24)= 2.53$, $p <.05$; Expt 2: $t(18) = 2.13$, $p <.05$). We assessed the magnitude of this effect within individuals by assessing how many standard deviations higher a face is rated in a group than alone. In both experiments we found an effect size of about 1/20th of a standard deviation (Expt 1: 5.59%, Expt 2: 5.56%). These findings indicate that automatic averaging of faces produces a summary representation that is more attractive than the faces from which it was derived, and that this representation biases the individual faces in the set to be perceived as more attractive.

43.443 **Disagreements about the attractiveness of faces arise largely from past experiences: evidence from twins** Jeremy Wilmer[1](jwilmer@wellesley.edu), Richard Russell[2], Matthew Bronstad[3], Holum Kwok[1], Samuel Anthony[4], Laura Germine[5]; [1]Department of Psychology, Wellesley College, [2]Department of Psychology, Gettysburg College, [3]Schepens Eye Research Institute, Harvard Medical School, [4]Department of Psychology, Harvard University, [5]Center for Human Genetic Research, Harvard Medical School

Introduction: Though individuals agree considerably on which faces they find more and less attractive, robust disagreements exist as well (Bronstad & Russell, 2007). Here, we investigate the origins of these disagreements, using a classic twin study to probe the relative contributions of genes and environments to idiosyncrasy of taste (IOT). Methods: A total of 284 twin pairs, 196 monozygotic (MZ) and 88 dizygotic (DZ), rated 200 faces on a scale of 1 ("very unattractive") to 7 ("very attractive"). We measured IOT as each individual's divergence from the mean person's ratings, or one minus the squared correlation of their ratings with the mean person's ratings. In order to distinguish idiosyncrasy from inconsistent or careless responding, we repeated 60 faces and confirmed that results were robust to controlling for inconsistency of responses across the two repetitions. Results: IOT varied widely and reliably across individuals (mean=0.55, SD=0.12, reliability=0.90). As this reliability greatly exceeded the MZ twin correlation (0.26, p-value of difference <0.00001), a large amount of the reliable variation in IOT is attributable neither to the genes nor to the environmental factors that MZ twins share, but rather to the highly individual factors that make an MZ twin different from his or her co-twin. The MZ correlation was somewhat higher than the DZ correlation of 0.19, but the difference was not statistically significant, suggesting that genetic influence has, at most, a minor influence on IOT. Conclusion: We conclude that disagreements on the attractiveness of faces arise largely from highly individual past experiences of the sort that differ even between two monozygotic twins. We propose that whatever evolutionary forces operate on facial aesthetic preferences may favor the adaptability of these preferences to the particulars of one's environment.

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43.444 **Above Average? Perceptions of attractiveness in children and adults** Larissa Vingilis-Jaremko[1](vingilln@mcmaster.ca), Marlette Ravelo[1], Daphne Maurer[1]; [1]McMaster University

Adults rate averaged faces approximating the population mean as more attractive than most individual faces (e.g., Langlois & Rogmann, 1990). However, an average created from highly attractive faces is judged by adults to be more attractive than an average created from a wider selection of faces (Perrett et al. 1994, DeBruine et al. 2007). We created two 'attractiveness dimensions': one of 21 male faces and the other of 21 female faces, each based on the differences between a typical average and an attractive average. We exaggerated the differences by up to 500% on either side of the typical averages. Adults (n=20) rated the attractiveness of each face, and judged the most attractive faces to be 'above average' (in the direction of the attractive average) on the attractiveness dimension for both male and female faces. To explore perceptions of 'the attractiveness dimension' developmentally, 5-year-olds (n=20) and a separate group of adults (n=20), viewed pairs of faces that varied along the attractiveness dimension and selected which face was more attractive. Regardless of pairing and gender of face, adults selected the face nearer the attractive average as more attractive. Across the pairings of male faces, five-year-olds selected faces closer to the attractive average to be more attractive to the same extent as adults. However, for female faces, the effect was weaker in children than in adults and for some pairings, not significantly different from chance. The results indicate that the 'attractiveness dimension' already influences judgments of attractiveness by age 5, but to a greater extent for male than female faces. The results suggest influences on attractiveness in addition to cognitive fluency for processing average faces emerge early in development. Surprisingly, the results suggest greater maturity on this dimension for male than female faces.

43.445 **The Effect of Motion on Facial Attractiveness Ratings** Knoch John M.[1](johnknoch@csu.fullerton.edu), Peissig Jessie J.[1]; [1]California State University, Fullerton

In our everyday encounters, we perceive dynamic faces and evaluate them for various characteristics including attractiveness. Most research on attraction has mainly relied on the use of static (non-moving) images. However, recent studies suggest that dynamic (moving) faces are evaluated differently than non-moving faces (Rubenstein, 2005) and that there may be

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additional features hidden in motion that are lost in static images (Lander, 2005). In this study, we recorded models expressing emotional expressions. Using these videos we created apparent-motion stimuli as well as stimuli that displayed the exact same frames, but did not have the effect of motion. Next, participants were asked to rate the models on a Likert scale ranging from 1 (very unattractive) to 7 (very attractive). Each participant was assigned to a movement condition (static or dynamic) and rated both male and female models in different emotional context trials (happy, sad, surprised, and angry). Data from 28 participants were analyzed. We found a significant difference between the ratings of male models in the dynamic ($M = 2.36$, $SD = 1.24$) and static ($M = 2.71$, $SD = 1.36$) conditions, as well as an interaction between the type of expression and movement condition for the male models $F(3, 104) = 5.37$, $p = .002$. For females, the dynamic stimuli were rated as more attractive than the static, however this difference was not significant. The direction of the trends suggests that there may be a sex difference in how motion contributes to attractiveness ratings. These data suggest that motion does contribute to perceived attractiveness, however these effects appear to be modulated by other factors.

Acknowledgement: California State University Fullerton Faculty/Student Creative Activity Grant

43.446 **Cues to health impact perceived trustworthiness and attractiveness**

Milena Dzhelyova[1,2], Carmen Lefevre[2], David Perrett[2]; [1]Face Categorization lab, Université catholique de Louvain (UCL), [2]Perception lab, School of Psychology and Neuroscience, St Andrews University

Cues to health are crucial for mate choice and for judgments of who to trust in social interactions. Skin colour cues current health, while masculinity may cue long-term health, it is also associated with negative personality traits (e.g. uncooperativeness). We therefore investigated the contributions of facial skin colour and masculine face shape to attractiveness and trustworthiness perception. Male faces were manipulated in both skin colour (healthy/unhealthy) and face shape (feminine/masculine). Healthy colour increased attractiveness and trustworthiness ratings. Feminine-shaped faces were perceived as more trustworthy while masculine-shaped faces were perceived as more attractive. Attractive male faces either had a healthy colour or a masculine shape, but possession of both characteristics did not elevate attractiveness further. The results suggest that the interplay between cues for mate choice is more complex than previously thought.

43.447 **Rapid Summarisation of Attractiveness in Groups**

Richard J Carvey[1](r.carvey@2010.hull.ac.uk), Katherine M Fielding[1], Chang Hong Liu[1]; [1]Department of Psychology, University of Hull

To process the abundance of visual stimuli available to us on a daily basis, our visual system often handles redundancy by compressing similar items into an ensemble representation (Alvarez, 2011). This can be something as comparatively simple as the size of a set of circles (Ariely, 2001), or as complex as the expressions of multiple faces (Haberman & Whitney, 2009). We investigated whether this compression also occurs for the attractiveness of faces. Attractiveness of a single face can be accurately judged from incredibly short exposures (Olson, 2005). We tested whether an accurate estimate of attractiveness can also be summarised from multiple faces. Participants saw sets of nine faces for varying display durations (250, 500, 1000ms, and an unlimited condition) and were asked to indicate whether it contained more attractive or more unattractive faces. We found performance was higher than chance in all but the most difficult conditions, and improved with a clearer majority, with generally better performance when this majority was unattractive. Longer exposures also increased performance, but 1000ms proved as sufficient as the unlimited condition. During this task we recorded eye movements to establish whether attractive or unattractive faces were drawing visual attention. The order of fixations to spatial locations was unaffected by the attractiveness of either the set or the face in the location. Common scan paths in the two shortest displays did not vary between accurate and inaccurate trials, remaining centrally focussed. For 1000ms, accurate trials showed slightly more systematic patterns than inaccurate trials, and the unlimited condition showed a left-to-right top-to-bottom reading pattern for accurate trials that was absent from inaccurate trials. Longer exposures appear to improve performance (often with more faces being fixated), suggesting that in brief exposures limited sampling may lead to an ensemble that is incomplete, but still allows some accurate performance.

43.448 **Culture shapes neural representations for faces: an eye movement and fMRI study**

Xinyi Ouyang[1](xinyi.ouyang@unifr.ch), Luca Vizioli[1], Meike Ramon[2,3], Roberto Caldara[1]; [1]Department of Psychology, University of Fribourg, Switzerland, [2]Centre for Cognitive Neuroimaging (CCNi), University of Glasgow, UK, [3]Department of Psychology, University of Louvain La Neuve, Belgium

Globalization is a unique phenomenon in human history and a constitutive feature of modern societies. Exposure to diverse cultural groups is quickly becoming the norm and the understanding on how culture shapes human cognition a fundamental question for neuroscientists. We recently found that the face system flexibly engages into local or global eye movement strategies across cultures, by relying on distinct facial features (i.e., the eyes for Westerners, the central region of the face for Easterners) and culturally tuned spatially filtered information. These observations challenge the view of a unique putative process for face processing. Yet, the underling neural mechanisms of this cultural perceptual tuning have never been directly investigated at the neural level. To address this question, we simultaneously recorded the BOLD signal and the eye movements of Western and Eastern observers while performing an old/new face recognition and race categorization tasks with Western and Eastern faces. Importantly, we parametrically varied the available spatial frequency (SF) content using Laplacian pyramids, thus simulating visual information at different viewing distances. We computed representational similarity matrices in 4 face-sensitive Regions of Interest (right and left Fusiform Face Area, and Occipital Face Area) by correlating the neural activity elicited by the different level of SFs, independently per task and face races. Culturally specific eye movement patterns emerged with increased availability of SF content. Importantly, Easterners displayed their typical global fixation pattern earlier (i.e. with less high SF) than Western observers. Critically, these behavioral differences, with their relative task constraints, modulated the neural representations in the rFFA only. Our data show that culture shapes face processing, by tuning the eye movements, SF information intake and neural representations. These findings reinforce the view that the face system does not subserve universal computational rules and provide novel insights on human diversity.

Acknowledgement: This study was supported by the Swiss National Science Foundation (100014_138627).

43.449 **No role for lightness in adaptation for Black and White: Race-contingent face aftereffects depend on facial morphology, not skin tone**

O. Scott Gwinn[1](scott.gwinn@mq.edu.au), Kevin R. Brooks[1]; [1]Department of Psychology, Macquarie University

Adaptation and aftereffects are useful tools in revealing the structure of visual processing mechanisms. That opposing aftereffects can be simultaneously induced using faces of different race indicates the existence of dissociable pools of neurons sensitive to race. Research into race-contingent face aftereffects suggests that such effects cannot be accounted for solely by adaptation to physical properties of the stimulus. Instead, higher level judgments of race are involved. Investigations into the factors that determine perceptions of race indicate that such judgements are primarily based on facial morphology with little influence of skin tone. Together, these findings suggest that race-contingent face aftereffects should be more substantially influenced by differences in morphology than by skin tone. To test this, opposing aftereffects involving distortions of expansion and contraction were measured for African and Caucasian face pairs differing in both morphology and skin luminance (condition 1), differing only in morphology (condition 2) and differing only in skin luminance (condition 3). Significant opposing aftereffects were found in conditions 1 and 2, but not 3. Furthermore, the strength of the aftereffect found in condition 2 was not significantly different to that found in condition 1, suggesting that race-contingent face aftereffects can be accounted for by differences in morphology alone. These results support a growing body of work indicating that the neural mechanisms involved in perceiving race are primarily sensitive to morphology and not skin tone.

43.450 **The Role of Race in Summary Representations of Faces**

Won-Mo Jung[1,2](croquies@korea.ac.kr), Isabelle Bülthoff[1,2], Ian Thornton[3], Seong-Whan Lee[1], Regine Armann[1,2]; [1]Dept. of Brain and Cognitive Engineering, Korea University, South Korea, [2]Dept. of Human Perception, Cognition and Action, Max Planck Institute for Biological Cybernetics, Germany, [3]Dept. of Psychology, Swansea University, UK

One possibility to overcome the processing limitation of the visual system is to attend selectively to relevant information only. Another strategy is to process sets of objects as ensembles and represent their average characteristics instead of individual group members (e.g., mean size, brightness, orientation). Recent evidence suggests that ensemble representation might occur even for human faces (for a summary, see Alvarez, 2011), i.e., observers can extract the mean emotion, sex, and identity from a set of faces (Habermann & Whitney, 2007; de Fockert & Wolfenstein, 2009). Here, we extend this line of research into the realm of face race: Can we extract the "mean race" of a set of faces when no conscious perception of single individuals is possible? Moreover, does the visual system process own- and other-race

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faces differently at this stage? Face stimuli had the same (average) male identity but were morphed, at different levels, in between Asian and Caucasian appearance. Following earlier studies (e.g., Habermann & Whitney, 2007, 2010), observers were briefly (250ms) presented with random sets of 12 of these faces. They were then asked to adjust a test face to the perceived mean race of the set by "morphing" it between Asian and Caucasian appearance. The results show that for most participants the response error distribution is significantly different from random, while their responses are centered around the real stimulus set mean - suggesting that they are able to extract "mean race". Also, we find a bias towards responding more "Asian" than the actual mean of a face set. All participants tested so far are South Korean (from Seoul), indicating that even at this early (unconscious) processing stage, the visual system distinguishes between own- and other-race faces, giving more weight to the former. Follow-up experiments on Caucasian participants will be performed to validate this observation.

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43.451 **Reducing the other-race effect requires childhood visual experience, not increased social motivation** Lulu Wan[1,2](lulu.wan@anu.edu.au), Elinor McKone[1,2], Jessica L. Irons[1], Kate Crookes[3]; [1]Research School of Psychology, The Australian National University, Australia, [2]ARC Centre for Excellence in Cognition and Its Disorders, The Australian National University, Australia, [3]School of Psychology and ARC Centre for Excellence in Cognition and Its Disorders, University of Western Australia, Australia

AIMS. The other-race effect (ORE) refers to poor ability to tell apart members of other races. Here, we contrast two theoretical approaches to explaining the ORE. The first is a lack of visual experience, leading to perceptual mechanisms for individuating faces (e.g., face-space dimensions) being tuned to one race and thus less useful for discriminating faces of other races. The second is the Hugenberg et al (2007) hypothesis that the ORE is due to lack of motivation and can be overcome by instructions to pay greater attention to individuating information in the other-race faces. METHOD. Unlike Hugenberg, we tested the full crossover design (Asian and Caucasian observers, on Asian and Caucasian faces), tested face recognition rather than photograph recognition by using new images of the person (Cambridge Face Memory Test format), and asked observers to report their effort applied to individuating other-race faces. Subjects also reported multiple contact variables (e.g., percentage of Asians in their classes) separated into different life stages (primary school, secondary school, and now). Results. Findings showed (a) in our populations, the Hugenberg motivation-to-individuate instructions produced no reduction in the ORE (but improved memory overall); (b) participants were highly motivated to individuate other-race faces even without the Hugenberg instructions, yet showed a strong ORE; (c) the size of individuals' ORE correlated with their contact with different races in childhood; (d) there was no correlation between ORE and either social attitudes (willingness to marry other-race person) or recent contact as adults. Conclusions. Results support the lack-of-visual-experience theory not the lack-of-motivation theory. Increasing attention to other-race faces is not sufficient to reduce the ORE. Instead, visual experience is required. Moreover, this experience with other-race faces must be obtained in childhood, suggesting tuning of face mechanisms to particular subtypes of faces has a period of greater plasticity during development.

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43.452 **Multiracial experience leads to increased discriminability of facial features but not configural dimensions** Ayla Byrd[1,2](ayla.byrd.10@cnu.edu), Noah Schwartz[1,2]; [1]Neuroscience Program, Christopher Newport University, [2]Department of Psychology, Christopher Newport University

Face recognition ability is enhanced by experience; the more familiar an individual is with a particular race, the more they are able to distinguish between similar faces within that race. The current study examined a related question: How does face processing change for individuals who have experience with other races compared to individuals who have only experienced one race? We used a two-part experiment to independently measure face discrimination ability and face recognition strategy, and compared the performance of caucasian individuals with multiracial experience to caucasian individuals who had monoracial, or limited multiracial experience. Multiracial experience was assessed using an "Ethnohistory Survey" that assessed the individual's depth of cross-racial social experience. In Part 1 of the experiment, we measured face discrimination thresholds for seven internal face dimensions (i.e. eye shape, nose-mouth distance, etc) using a same-different task. Face stimuli were caucasian and were displayed in grayscale, and an adaptive thresholding procedure (QUEST) was used. In Part 2 of the experiment, we measured face recognition strategy using a 3-alternative forced error (3-AFE) design, a modified 3-AFC, delayed match-to-sample task in which there is no correct answer. Distractors were calibrated using thresholds measured in Part 1 and each distractor varied in only one dimension from the target so participant response indicated the dimension with the least utility. Results show that observers with multiracial experience are more sensitive to differences in featural information (e.g. eye shape, nose shape) compared to individuals with limited experience. Discrimination thresholds did not differ for configural dimensions (e.g. eye-eye distance). Furthermore, the utility of each dimension did not differ between groups. Overall, results suggest that experience with multiple races increases sensitivity to the shape of facial features, but does not change sensitivity to facial configural information or the recognition decision strategy used by the observer.

43.453 **Individual differences in holistic processing predict the own-race advantage in recognition memory** Andrew Rosenblatt[1](andrew.s.rosenblatt@gmail.com), Rogelio J. Mercado[2], Jeremy Wilmer[3], Joseph DeGutis[1,4]; [1]Boston Attention and Learning Lab (BALLAB), VA Boston Healthcare System, Jamaica Plain, MA, United States, [2]Department of Psychology, Temple University, [3]Department of Psychology, Wellesley College, [4]Vision Sciences Laboratory, Department of Psychology, Harvard University

Individuals are consistently better at recognizing own-race faces compared to other-race faces (other-race effect, ORE). One popular hypothesis is that this recognition memory ORE is caused by differential own- and other-race holistic processing, the simultaneous integration of part and configural face information into a coherent whole. Holistic processing may create a more rich, detailed memory representation of own-race faces compared to other-race faces. Despite several studies showing that own-race faces are processed more holistically than other-race faces, studies have yet to firmly link the holistic processing ORE (HP-ORE) with the recognition memory ORE (RM-ORE). With the participation of 53 Caucasian individuals (mean age of 24.91 years), the current study demonstrates such a linkage by using validated measures of holistic face processing (Caucasian and Asian part-whole tasks) and face recognition (Caucasian and Asian Cambridge Face Memory Tests) and employing a regression-based approach that enables fine-grained parsing of individual differences in these OREs. This analytic approach allows us to separately examine (a) own-race-specific performance, statistically equating other-race performance across individuals, and (b) other-race-specific performance, statistically equating own-race-specific performance across individuals. Using this approach, we found an association between HP-ORE and RM-ORE that was largely specific to own-race performance, thereby linking own-race-specific holistic processing mechanisms to the RM-ORE. We also demonstrated that own-race performance across all of our tasks correlated highly with other-race performance, suggesting that the mechanisms used for own- and other-race face processing are mostly shared. We also replicate previous findings that own-race faces are processed more holistically than other-race faces, and show that this is specific to the eye region. Together, these results suggest that while own- and other-race faces recruit largely similar mechanisms, own-race faces more thoroughly engage holistic processing, and moreover, those individuals who preferentially engage holistic processing mechanisms for own-race faces show an own-race-face-specific recognition advantage.

Acknowledgement: Veterans Affairs Career Development Award for JD

43.454 **The eye-size illusion is affected by face race, but not face orientation** Wen Sara Xiao[1](xiaowen0423@gmail.com), Yu-Hao Sun[2], Paul C. Quinn[3], Justine M. Thacker[1], Naiqi G. Xiao[1], Genyue Fu[4], Kang Lee[1]; [1]Dr. Eric Jackman Institute of Child Study, University of Toronto, [2]Psychology, Zhejiang Sci-Tech University, [3]Department of Psychology, University of Delaware, [4]School of Education, Zhejiang Normal University

An eye-size illusion is generated by the size transformation made on a stimulus face: when changing the size of the face frame (i.e., the whole face except the eyes), perceived size of the eyes is altered (Rakover, 2011). The current study aimed to measure more fully the magnitude of the illusion and investigate how it was affected by stimulus inversion and race. For each face stimulus, we produced 10 variants by changing the size of the original face frame (except for the eye-area) to a different extent from 86% to 114%. The variants were paired with the original face and a group of adult Chinese participants with no direct experience with Caucasian faces were asked to select the face in which the eyes were perceived to be larger. Using the percentage of responses on which the original face was selected as the dependent measure and testing it against 50% chance level, the illusion was most clearly observed when the variant faces were

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below 96% or above 104% of the original faces in the Chinese Upright condition. Thresholds for Chinese Inverted faces (below 96% or above 106%) were similar as for the Chinese Upright faces, indicating the absence of an inversion effect. However, thresholds for Caucasian Upright faces were below 94% or above 114% of the original faces, suggesting that the illusion is more robust for own- than other-race faces. Thresholds for Caucasian Inverted faces were below 90% or above 114%, similar to the thresholds in Caucasian Upright condition. Our data provide estimates of the eye-size illusion and how its magnitude is affected by face orientation and race. The absence of an inversion effect in own-race faces suggests that the illusion is unrelated to configural processing. The presence of a race effect suggests that experience plays a role in producing the illusion.

43.455 **Social group knowledge biases face perception** Sara C. Verosky[1](sverosky@fas.harvard.edu), Nicholas B. Turk-Browne[2,3], Alexander Todorov[2,3]; [1]Department of Psychology, Harvard University, [2]Department of Psychology, Princeton University, [3]Princeton Neuroscience Institute, Princeton University

Individuals readily learn and keep track of the social group membership of people around them. Although this knowledge is often not visual, here we investigate the surprising possibility that it can nevertheless bias visual processing of faces. In Experiment 1, participants learned that novel faces belonged to students enrolled in either an engineering or humanities major. During this learning phase, participants viewed a name, major, and brief biographical description of each person, and then viewed the person's face for 9s. During a subsequent evaluation phase, participants indicated to what extent they thought each face looked like a typical engineering or humanities major. Faces that were randomly assigned to both the engineering and humanities majors were rated as more typical of their respective groups, as compared to the ratings of a control group who did not complete the learning phase. Because this perceived typicality could result from demand characteristics, participants in Experiment 2 were explicitly told that the pairings of faces and majors were completely random. Despite this manipulation, faces were still rated as more typical of their respective groups. These results suggest that knowledge about social group membership biases face perception compulsorily. To build on this behavioral effect, Experiment 3 investigated the influence of social group information on neural representations of faces using fMRI. Participants first completed a similar learning phase to that described above, and then they viewed pairs of faces belonging to the same person, the same social group, or different social groups. Adaptation and multivariate pattern analysis are used to identify representations of individuals and social groups. Our results suggest that higher-order social knowledge can intrude in perceptual judgments, and they concur with the common intuition that people seem to 'look' like they belong in their social group.

Acknowledgement: NIH R01 EY021755 (NTB)

43.456 **Bubblizing social face perception** Karolann Robinson[1](robk11@uqo.ca), Justin Duncan[1,2], Caroline Blais[1], Forget Hélène[1], Fiset Daniel[1]; [1]Département de Psychoéducation et Psychologie, Université du Québec en Outaouais, [2]Département de Psychologie, Université du Québec à Montréal

When asked to judge an unknown face on social traits such as trustworthiness and dominance, a high level of agreement is found among people, suggesting that some visual information in faces correlates with these judgements (Oosterhof & Todorov, 2008). We used the Bubbles technique (Gosselin & Schyns, 2001) to reveal the visual information used to judge the trustworthiness (Exp. 1) and dominance (Exp. 2) of 300 faces. Participants (N=50 for each experiment) were presented with either bubblized faces (phase 1) or fully visible faces (phase 2) and were asked to judge the level of trustworthiness or of dominance of the stimuli using a nine-level Likert scale. The number of bubbles was kept constant (i.e., 65 bubbles) across participants and trials. The judgements obtained for each fully visible face were considered "accurate" for a given participant. The judgements obtained with the same bubblized faces were possibly influenced by the available information. Thus, the following analyses allowed us to verify how judgements were influenced by the visual information available for the task. For each experiment, a classification image showing which visual information favoured the percept of trust or of dominance was computed by performing a multiple linear regression on the bubbles' location and on the difference (i.e., transformed into z-scores) between the bubbles judgements and the accurate judgements. For trust judgements, the areas used were: the eyes in the spatial frequency (SF) bands ranging from 21 to 84 cycles per face (cpf); the mouth in the SF bands ranging from 42 to 84 cpf and from 10 to 21 cpf; and most of the face in the two lowest SF bands. The dominance judgement was based mostly on the utilization of the eyebrows area in mid-to-high SFs. Interestingly, these two judgements were based on orthogonal visual information.

43.457 **Reduced Interference Between Identity and Expression Processing With Dynamic Faces** Brenda Stoesz[1](sbrenda@mymts.net), Lorna Jakobsona[1]; [1]Department of Psychology, Unviversity of Manitoba

Facial motion cues facilitate identity and expression processing (Pilz et al., 2006). To explore the possible basis of this dynamic advantage, we used Garner's selective attention paradigm (Garner, 1976) to determine whether adding dynamic cues alters the way that identity and expression processing interact, and whether this varies depending on the age of the viewer. Adults (ages 18-26), adolescents (ages 12-13), and children (ages 6-7) made speeded judgments of the expression (or identity) of static and dynamic faces while identity (or expression) was either held constant (baseline block) or varied (orthogonal block). Accuracy was high (>90%) for all three age groups. We calculated corrected Garner interference scores by determining the percent change from baseline RT seen in the orthogonal block. A 2 (Task: Expression, Identity) X 2 (Mode: Static, Dynamic) X 3 (Age Group: Adult, Adolescent, Child) ANOVA conducted on these scores revealed that interference was stronger in the Expression than in the Identity task, and with static compared to dynamic faces. However, follow-up tests conducted on the significant Task X Mode interaction showed that, while the addition of dynamic cues led to a significant reduction in Garner interference for both tasks, the effect was much more dramatic for the Expression task. Although young children took significantly longer than adolescents or adults to make their judgments, no age-related differences in Garner interference were observed. Reductions in interference after the introduction of dynamic cues might arise if viewers focus more selectively on specific facial features, or if they integrate multiple cues more effectively, when viewing moving as opposed to static faces. Both of these ideas hold merit and, indeed, it is possible that individual differences in processing style determine which strategy a viewer will adopt. These results highlight the importance of using naturalistic, dynamic stimuli in studies of face processing.

Acknowledgement: Natural Sciences and Research Council of Canada

43.458 **Invariant properties of detecting personal familiarity in "thin slices" of behavior** Alyson Saville[1](alyson.saville@ndsu.edu), Benjamin Balas[1]; [1]Center for Visual and Cognitive Neuroscience, Department of Psychology, North Dakota State University

Glimpses of nonverbal behavior (or 'thin slices') offer ample visual information to make reliable judgments about individuals. Previous work has largely focused on personality characteristics and traits of the individual; however the nature of dyadic relationships (strangers, lovers, or friends) can also be determined (Ambady & Gray, 2002). Judgments from thin slices are known to be accurate, but the visual features supporting accurate performance are unknown. We explored (1) whether personal familiarity was detectable within the context of 'thin slices' of genuine interaction and (2), the invariant properties of thin-slice recognition. We asked participants to discriminate between familiar and unfamiliar social interactions in two experiments. In each task, participants sequentially viewed two 6-s silent videos on each trial. One clip depicted an individual interacting with an unfamiliar partner; the other depicted the same person interacting with a personally-familiar partner. All sequences were cropped so that only the target individual was visible. In Experiment 1, participants viewed either the original sequences (N=16), reversed sequences (N=16), or a static-image "slideshow" of the sequence (N=16). In Experiment 2, all participants viewed the original sequences and either clips played at double-speed (N=18) or half-speed (N=18). Participants in Experiment 1 classified the videos at above chance levels in the forward (M=60.4%) and reverse (M=60.6%) conditions, but were significantly better in the static-image slideshow condition (M=71.4% - One-way ANOVA, p = 0.018). In Experiment 2, we observed a main effect of task speed (p = .046), indicating a larger performance cost for fast videos compared to slow videos. We conclude that detecting personal familiarity via spontaneous natural gesture depends on information in static images more than face or body movement. While static images are typically less important for recognizing nonverbal behavior, we argue they may be valuable for making familiarity judgments from thin slices of behavior.

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Multisensory processing: Sensory interaction

Monday, May 13, 8:30 am - 12:30 pm

Poster Session, Vista Ballroom

43.501 **Exploiting Crossmodal Correspondences To Make Auditory Sensory Substitution Interpretation Effortless** Noelle Stiles[1](nstiles@caltech.edu), Shinsuke Shimojo[1]; [1]Computation and Neural Systems, California Institute of Technology

Background: Worldwide 45 million people are blind. Sensory substitution (SS) may restore visual function by encoding visual information into a signal perceived by another modality, such as somatosensation or audition. However no devices are commercially available due to long training duration, top-down attention requirements, and resulting low-functionality. Enhancing the intuitiveness of devices is critical to their wider use. Crossmodal correspondences, or intrinsic (crossmodal) mapping, are relations that exist across all modalities (such as high spatial position and high-frequency sounds) and are often used in SS encodings. By initiating SS training with crossmodal correspondence primitives and gradually building complexity, SS may become less attention-intensive and more intuitive. Method: Texture stimuli were distinguished between by naïve (no instruction, nor training on the device encoding) and trained SS users. Subjects listened/viewed to all sounds and image alternatives of each set and then paired a sound with an image (3AFC). Blind subjects used SS sounds and image reliefs. Results: Naïve and trained subjects performed above chance on a majority of simple and complex textures tested (on 15/16 sets), ranging from a set of images of lines of different thickness, a set of circles patterns of different sizes, and a set of natural textures. Texture interfaces (two textures with different border geometries) were also tested; naïve and trained sighted subjects performed above chance on 7 of 8 image sets. Naïve blind were tested on distinguishing lines of different thickness, circles patterns of different sizes and performed above chance. The accuracy difference between trained vs. naïve sighted groups was found to weakly correlate with image complexity (number of brightness levels and an edge-counting metric), and weakly inversely correlate with image repetitiveness. Discussion: Intuitiveness generated by intrinsic crossmodal mapping may be used to improve and shorten training procedures.

43.502 **Vision vs. Hearing: Direct Comparison of the Human Contrast Sensitivity and Audibility Functions.** Russell J. Adams[1,2](michelem@mun.ca), Paul Sheppard[1], Avineet Cheema[1], Michele E. Mercer[1]; [1]Department of Psychology, Faculty of Science, Memorial University, St John's NL Canada., [2]Discipline of Pediatrics, Faculty of Medicine, Memorial University, St John's NL Canada.

Purpose: Among the five human senses, vision and hearing are considered to be the most sophisticated due to their substantial representation within the cortical regions of the central nervous system. Surprisingly, although there is some understanding of higher levels of bimodal perception, there has been little investigation of the relationship between the more fundamental aspects of human vision and hearing. Here we explore this issue by examining whether human adults show comparable thresholds across a broad spectrum of basic visual patterns and acoustic stimuli. Methods: Spatial contrast sensitivity (CS) was measured in 45 young adults (M = 23 y) with two sine wave-based tests of contrast sensitivity (FACT, Vector Vision) spanning a wide range of spatial frequencies (1.5 to 18 cy/deg). Optical correction was worn if necessary. In the same session, subjects underwent a complete binaural audiology exam (GSI 17 audiometer) which assessed pure tone thresholds from 250 to 8000 Hz. Individual subject data was also collected from 12 adults who were evaluated repeatedly with all tests over 10 additional sessions. Results: To evaluate the vision and hearing data more directly, contrast sensitivity functions for each subject were inverted to yield threshold functions which are more comparable to the threshold audibility functions obtained with the audiometer. Analyses revealed that although there were no relationships between individual visual and auditory frequencies, composite measures revealed that adults' total CS across all SF correlated with total audibility values ($p < 0.05$), especially among the adults tested repeatedly. Conclusions: The present results imply that human adults show a relationship between threshold levels of hearing and vision, at least in terms of the overall stimulus area defined by the CS and audibility functions. This finding suggests that for individual adults, there is some commonality in basic functioning between the two sensory systems with the human CNS.

Acknowledgement: NSERC (Canada) Janeway Hospital Research Foundation

43.503 **Long-term change of vestibular state alters the visual responses to biological motion** Xue Zhang[1](zhangxue@psych.ac.cn), Ying Wang[1], Dong Liu[1], Qian Xu[1], Yi Jiang[1]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Psychology, Chinese Academy of Sciences

Message of gravity is transformed into the senses of the gravitational "up" and a force that pulls things "down" by the vestibular system. Little is known about whether and how such information is integrated with other sensory cues in conscious perception. It has been documented that visual gravitational motion can activate the vestibular cortex where the internal model of gravity is stored. However, the influence of vestibular state on visual perception has been scarcely investigated. Here we examined whether long-term change of vestibular state may alter the activity of visual cortices using -60 head-down bed rest, an approach widely used to simulate weightlessness. We recorded, both before and after 45 days of bed rest, observers' neural responses to upright and inverted biological motion, face and house stimuli, as well as their brain activities in the resting state. Significant drop of neural inversion effect (NIE) in the pSTS for biological motion was found after bed rest, but not for faces in the FFA, or for houses in the PPA, suggesting that long-term vestibular state change modulates visual processing that specifically involves gravitational motion. More importantly, the change observed in the pSTS was not evident in the MT and FBA that are respectively dedicated to basic motion and static body perception, implying a specialized mechanism tuned to the processing of biological motion per se. Brain connectivity analyses further showed a significant correlation between the change of connectivity from vestibular cortex to pSTS and the change of biological motion perception following the bed rest. These findings provide clear evidence that the change of vestibular state alters the visual responses to gravitational biological motion information, thus broadening our understandings of the vestibular contribution to conscious perception.

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43.504 **Modulation of Vestibular Evoked Reflexes in Postural Muscles During Self-Motion Experiences in a Virtual Simulation** Fabricio Saucedo [1](fsaucedo3@miners.utep.edu), Rebecca Reed-Jones[1]; [1]Department of Kinesiology, The University of Texas at El Paso

Hidden formatting deleted. Delete this text! mso-layout-grid-align:none;-text-autospace:none">Maintaining posture requires the integration of several systems: musculoskeletal, somatosensory, visual, and vestibular. The visual and vestibular systems contribute the greatest amount of information regarding the environment and the position and orientation of the body with respect to the environment. Therefore, how visual and vestibular systems work together is critical to understanding how humans maintain upright stance. The purpose of this study was to determine if dynamic visual stimuli alter central vestibular function and/or modify motor commands for postural control. Ten young adults performed 20 standing trials (60-second duration) in four sensory conditions: Control (No stimulus), Visual Only, Galvanic Vestibular Stimulation (GVS) + Visual, and GVS Only. Participants stood quietly on a force platform with their heads turned at a 90-degree angle with gaze directed to a screen at their side. Measures of center of pressure (COP) variability assessed postural control during the four sensory conditions. The analysis of COP variability revealed a significant difference between the Visual Only and GVS Only conditions ($p < 0.05$) with COP variability being lowest in the Visual Only condition and greatest in the GVS Only condition. In the combined vestibular and visual condition, COP variability fell between the two single sensory conditions. These results indicate an interaction between the two sensory systems, where visual stimuli reduces vestibular influence on postural control. In addition to COP measures, EMG of the soleus, tibialis anterior, and gastrocnemius muscles were recorded bilaterally. Hidden formatting deleted. Delete this text! 15.0pt;font-family:"Times New Roman";mso-fareast-font-family:Cambria; mso-bidi-font-family:Calibri">Further discussion of these EMG measures and the modulation of GVS evoked muscle reflexes with altered visual input will provide further information regarding modulation of central vestibular function and postural control.

43.505 **Human cortical responses to congruent and incongruent combinations of visual and vestibular stimuli** Jac Billington[1](j.billington@leeds.ac.uk), Andrew Smith[2]; [1]Institute of Psychological Sciences, University of Leeds, Leeds, LS2 9JT, [2]Dept of Psychology, Royal Holloway, University of London, Egham TW20 0EX

Processing of visual cues to egomotion has been associated with hMST, hPIVC and CSv. All three areas are also implicated in vestibular processing (Smith et al. Cerebral Cortex, 2012). We explored whether and how vestibular and visual signals are combined in these regions. Whilst some neurons in macaque MSTd show the same directional tuning in both modalities, some show incongruent tuning preferences, suggesting a role in cancelling the effect of rotational head movements on optic flow during self-motion. We measured the perceptual magnitude of roll induced by galvanic vestibular stimulation (GVS) and measured the vestibulo-ocular reflex (VOR). GVS was then combined with fMRI to assess responses to matched vestibular and visual stimuli in two combinations: (i) visual rotation induced by GVS, nulled by counter-rotation of the visual stimulus and (ii) visual stimulus rotation in the same direction and with the same retinal magnitude as that induced by GVS. Responses in hMST, hPIVC and CSv were similar in both conditions. This result suggests that these areas respond to the degree of retinal motion, as opposed to the degree of motion consciously perceived. Such patterns of response may reflect the presence of populations of visual-vestibular neurons which are involved both in representing head rotation for perception of self-motion and in cancelling the visual effect of head rotation when computing object motion within the visual scene.

Acknowledgement: Leverhulme Trust

43.506 **Effects of head orientation on the perceived tilt of a static line and 3D global motion.** Pearl S. Guterman[1](pearljam@cse.yorku.ca), Robert S. Allison[1], James E. Zacher[1]; [1]Centre for Vision Research, York University, Toronto, Canada

When the head is tilted an objectively vertical (or horizontal) line is typically perceived as tilted. We explored whether this shift occurs when viewing 3D global motion displays. Global motion is processed, in part, in cortical area MST, which is believed to be involved in multisensory integration and may facilitate the mapping of spatial reference frames. Thus, we hypothesized that observers may be less susceptible to these biases for global motion compared to line displays. Observers stood, and lay left and right side down, while viewing a static line or random-dot 3D global motion display. The line and motion direction were tilted 0°, ±5°, ±10°, ±15°, ±20°, and ±25° from the gravitational vertical, and in a separate block tilted from the horizontal. After each trial, observers indicated whether the tilt was clockwise or counterclockwise from the perceived vertical or horizontal with a button press. Psychometric functions were fit to the data and shifts in the point of subjective equality (PSE) were measured. These shifts were greater when lying on the side than standing. These shifts were biased in the direction of the head tilt, consistent with the so-called A-effect. However, contrary to an earlier study by De Vrijer, Medendorp, and Van Gisbergen (2008, J Neurophysiol, 99: 915–930) that found similar PSE shifts for lines and 2D planar motion, we found significantly larger shifts for the static line than 3D global motion. There was no appreciable difference between the shift magnitude in the tilt-from-vertical and horizontal conditions. Furthermore, the direction of motion (up/down, left/right) had no significant influence on the PSE. The results will be discussed in terms of the sensory integration of motion information in cortical areas.

Acknowledgement: Ontario Graduate Scholarship, Ontario Ministry of Training, Colleges and Universities

43.507 **Decoding visual objects in somatosensory cortex: the effect of prior visuo-haptic experience** Fraser Smith[1](fraser.smith@glasgow.ac.uk), Melvyn Goodale[2]; [1]Institute of Neuroscience & Psychology, University of Glasgow, UK, [2]The Brain and Mind Institute, The University of Western Ontario, Canada

Neurons, even in the earliest sensory areas of cortex, are subject to a large number of contextual influences from both within and across modality connections. In previous work (Smith & Goodale, 2012, ECVP) we have shown that early regions of somatosensory cortex (S1) surprisingly contain content-specific information about visually presented object categories (i.e. in the absence of any tactile stimulation). In the present experiment, we investigate whether prior visuo-haptic experience with the object categories is necessary in order to observe this effect. In an fMRI experiment, we presented participants with visual images of either familiar visuo-haptic categories (wine glasses, mobile phones or apples; replicating our initial experiment) or artificially created visual shapes (cubies, spikies or smoothies; see Op De Beeck et al 2008). Participants fixated and performed an orthogonal task (counting the numbers of fixation cross color changes occurring in each run). We predicted that MVPA decoding of object category should be above chance in S1 and S2 only for the familiar visuo-haptic shape categories, whereas in visual cortex, decoding should be above chance for both familiar and unfamiliar categories. MVPA revealed reliable decoding in both S1 and S2 for familiar but not unfamiliar object categories. In contrast, in early vision, both unfamiliar and familiar object categories could be decoded with very high accuracy. Our findings suggest that visual presentation alone of familiar but not unfamiliar objects trigger content specific activity patterns even in the earliest regions of somatosensory cortex. Thus the present data support the idea that cross-modal activation of content-specific representations in early sensory cortices is based on prior experience of concurrent multi-modal stimulation (e.g. Meyer & Damasio 2009).

Acknowledgement: Canadian Institutes of Health Research NSERC Create

43.508 **Are visual texture-selective areas recruited during haptic texture discrimination?** Samantha Podrebarac[1](spodreba@uwo.ca), Melvyn Goodale[2], Jacqueline Snow[2]; [1]Graduate Program in Neuroscience, The Brain and Mind Institute, Natural Sciences Centre, The University of Western Ontario, London, ON, Canada, N6A 5B7., [2]The Brain and Mind Institute, Natural Sciences Centre, The University of Western Ontario, London, ON, Canada, N6A 5B7.

Shape and surface texture provide salient cues to object identity, both when objects are explored using vision and via touch (haptics). In vision, shape information is processed within the lateral occipital complex (LOC), while surface texture is selectively processed in medial ventro-temporal cortex, in the collateral sulcus (CoS) and parahippocampul gyrus (pHG). Accumulating evidence indicates that the LOC, despite its location within the ventral visual system, is also consistently recruited during haptic shape processing. Here we used fMRI to examine whether ventral 'visual' texture-selective areas are similarly recruited when observers discriminate surface texture via touch. We used a blocked design in which participants attended to, and made same/different judgments about, sequential pairs of 3-dimensional plastic objects. During each block, the stimuli varied either in their shape (but not surface texture), or their surface texture (but not shape). In half of the scans, participants explored the stimuli using vision alone, and in the remaining scans the stimuli were explored via touch alone. In vision, the strongest fMRI responses to surface texture (versus shape) perception were observed within medial ventral temporal cortex – a result consistent with recent fMRI findings in vision. When stimuli were explored via touch, however, the strongest fMRI responses to surface texture (versus shape) perception were observed dorsally, within the parietal operculum (in the vicinity of secondary somatosensory cortex) and inferior frontal cortex. Importantly, however, we also observed significant texture-selective fMRI responses in medial ventral temporal cortex within areas analogous to those recruited during visual texture discrimination. Our imaging data demonstrate for the first time that ventro-medial temporal areas known to process visual textures are also recruited during the perception of surface texture via touch.

43.509 **Handedness and the weighting of visual- proprioceptive information in position estimation: the effect of illusory visual position information.** Harriet Dempsey-Jones[1](h.dempseyjones@gmail.com), Ada Kritikos[1]; [1]The School of Psychology, The University of Queensland

In body position estimation, visual information is weighted more heavily than other sensory systems. When no visual input is available, there are predictable errors in proprioceptive judgements of body location. Are certain individuals better able to locate their limbs when no visual information is present? Strongly right-handed individuals 'over-represent' the right side of extrapersonal and body-space resulting in less accurate implicit body representation compared with strongly left-handed or ambidextrous individuals (termed "pseudoneglect"). We investigated whether a) differences in body representation exist for static perceptual judgements of limb position, and b) how false visual information about body location influences static perceptual judgements across hand dominance groups. First, we compared proprioceptive acuity in the absence of visual position information across hand used and handedness at varying spatial locations with respect to the body midline. Second, we reintroduced visual information to investigate modulation of proprioceptive position resulting from this false visual information (using the Rubber Hand Illusion paradigm). We predicted that left-handed individuals would display greater "blind" position acuity overall and that the RHI would be less effective in shifting their position sense compared with right-handed and ambidextrous individuals. Contrary to predictions, evidence for proprioceptive accuracy differences and leftward spatial biases in right handed individuals was equivocal. Interestingly, the ability to shift felt position of the limb using false information was again, similar between right- and left-handers. Rather, regardless of handedness the RHI was most effective for the dominant compared to the non-dominant hand. This indicates proprioceptive information about location is weighted more evenly with vision for the dominant hand compared with the non-dominant hand. We

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believe this is due to greater representation of this hand in the somatosensory cortex. Results will be discussed in the context of the role of handedness and laterality of brain function in the representation of body space.

43.510 Comparison of Visual and Somatosensory Thresholds in Human Adults

Michele E. Mercer[1](michelem@mun.ca), Paul A.S. Sheppard[1]; [1]Department of Psychology, Memorial University, St John's, NL Canada

Purpose: Although humans engage the environment constantly with all five senses, we still know relatively little about some aspects of sensory interaction, particularly the relationships between the primary senses (vision and hearing) and the secondary senses (taste, touch/pain, and smell). This is of interest both for our understanding of the links between the neural mechanisms which underlie the different senses, as well as for the diagnosis and treatment of sensory related disorders. The present study reports on the first study designed to explore the basic question of whether fundamental aspects of human vision are related to the somatosensory systems of touch and pain. Methods: Two essential measures of spatial vision (visual acuity, contrast sensitivity) and a measure of temporal vision (flicker fusion threshold) were assessed in 45 healthy young adults (M = 23 y). Within the same session, contact heat and pressure algometer pain threshold/tolerance, as well as touch thresholds (von Frey fibres) were obtained from several locations on each subject's left hand and arm. Individual subject data was also collected from 12 adults who were evaluated repeatedly over 10 additional sessions. Results: Correlational analyses within the group data revealed very little relationship between any aspects of vision (spatial or temporal) and any of the touch or pain measures. However, data from individuals tested repeatedly revealed that contrast sensitivity was related to pain tolerance obtained with both contact heat and with pressure algometry (both $p < 0.05$). Conclusions: The present results provide evidence that human adults may show a relationship between pain sensitivity and some aspects of spatial vision. Given that dopamine is heavily involved in both the processing of pain as well as spatial information in the cortex, this raises the interesting possibility that the observed co-variation in sensitivity may be explained by dopaminergic involvement.

Acknowledgement: NSERC

43.511 Audiovisual synchrony drives visual search with a right visual field bias

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Visual search for a modulating target in a modulating array is much easier when synchronized with an auditory transient. Here we show an asymmetry in synchrony-driven search efficiency across the visual field. Participants viewed a ring of 19 luminance-modulating discs while hearing a modulating tone. The modulating discs had unique temporal phases (–380 to +380 ms; 40 ms steps), with one synchronized to the tone. Participants did a speeded visual search for the synchronized disc, with modulations (auditory and visual) both sinusoidal or both square at 1.3 Hz. Target position was randomized and spatial distributions of search efficiency were compiled. Results show that sine modulations did not facilitate search (chance performance at all target phases), but square-wave modulations did: the target (phase = 0 ms) was frequently chosen, with tight error distributions (~120 ms wide) around zero-phase lag. Spatially, visual search varied over the visual field: error distributions were more tightly tuned temporally on the right side, especially the upper-right quadrant. These results show that synchrony-driven visual search: (i) requires synchronized transient signals, (ii) has a narrow integration window (±60 ms), and (iii) is spatially biased to the right visual field, suggesting a hemisphereic specialization for synchrony-driven visual search.

43.512 Frequency-Based Synesthetic Associations between Letters and Colors

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Grapheme-color synesthesia is a form of synesthesia in which an individual's perception of numbers and letters is psychologically associated with colors. Synesthetes typically associate each letter with a specific color, but the cause of these pairings is unknown. However, one potentially useful clue is that the pairings appear to be consistent within a language, but different across languages. To determine the cause of these particular letter-color pairings, this study compares the frequency of letters in natural language with the wavelength of their associated colors across English, Spanish, and German speaking synesthetes. The frequency of a letter was highly correlated with the wavelength of its associated color ($r2 \approx 0.7$). Frequent letters are typically more red and orange, while infrequent letters are typically blue or purple. Additionally, synesthetes show a tendency to associate more saturated colors with the most common letters ($r2 \approx 0.2$), whereas the luminance of the colors is less correlated with letter frequency ($r2 \approx 0.003$). Neurophysiologically, this pattern may be caused by the wavelength-specific color receptor neurons of visual area V4 being fused with the language processing neurons of the left middle temporal gyrus (LMTG) that perform semantic recognition. Nelson and Eagleman (2009) theorize that this fusion is caused by a genetic mutation on the sixteenth chromosome. This account, when combined with the current data, suggests that this mutation causes V4 and LMTG neurons to fuse, and that a young synesthete's exposure to natural language guides the specific color associations that are formed as a result.

43.513 The role of biological motion in audio-visual integration

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In multi-sensory integration, vision generally has little influence on auditory duration judgments (Walker & Scott, 1981); provided sufficient quality of the auditory signal (Alais & Burr, 2004; Wada et al., 2003). However much of this research uses visual stimuli that are either static (Soto-Faraco, Spence, & Kingstone, 2004) or exhibit apparent motion (Getzmann, 2007). Here we explore the role of continuous motion in explaining surprising previous findings that visible striking gestures can in fact influence the perception of tone duration (Schutz & Kubovy, 2009); an influence at odds with 'optimal integration' as it cannot be explained by auditory ambiguity (Schutz, 2009). Our findings suggest the illusion stems in part from differences in perceiving stimuli exhibiting biological motion vs. non-motion (i.e. unmoving dots). Our stimuli for the three experiments included two classes of dots: dynamic—based on long and short gestures used by a musician to strike a percussion instrument (used previously; Schutz, 2009) and static—based on single dots turning on for a 'long' or 'short' period of time. We asked participants to judge the durations of several sounds while ignoring concurrent visual stimuli. Overall, we found auditory duration ratings were strongly affected by visual duration when dots were dynamic, rather than static. However, we also found this effect was dependent upon our blocking structure. The illusion was strongest when participants experienced all of the dynamic visual stimuli before all of the static visual stimuli (Exp 1) or vice-versa (Exp 2); when intermingled the visual influence was minimal (Exp 3). We will discuss these results in light of currently theories of multi-sensory integration generally based heavily on experiments in which visual information is static, rather than dynamic as is experienced in our everyday perceiving.

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43.514 Multisensory redundancy gain partially mediated by stimulus detectability

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The redundant-target effect is a basic and well-replicated finding that participants respond faster to a multisensory target (a combined sound and light) than to a unisensory target (an isolated sound or light). This response speeding is generally attributed to superadditive effects at the level of individual neurons, such that the neural response to a multisensory stimulus is greater than would be predicted from separate responses to the individual unisensory stimuli. However, a multisensory stimulus presentation also enhances the detectability of its unisensory components. Here we investigated whether multisensory facilitation is mediated by crossmodal enhancements of unisensory components rather than or in addition to the integration of multisensory signals. To test this hypothesis, visual detection thresholds were estimated using a 2AFC staircase procedure for a brief visual flash (visual alone condition) and a flash paired with a synchronous auditory tone (auditory-visual condition). Replicating prior work, significantly lower detection thresholds were observed for visual targets paired with an auditory cue relative to visual targets alone (p=.02). These thresholds were then used in a subsequent go-no-go redundant-target task in which subjects responded to target stimuli in four conditions: (1) auditory-target alone, (2) visual-target alone at 120% visual alone contrast threshold, (3) auditory-visual target at 120% visual-alone contrast threshold, and (4) auditory-visual target at 120% auditory-visual contrast threshold. Conditions 2 and 3 presented flashes of equal contrast. The auditory-visual condition 4, however, presented physically dimmer but equally detectable flashes to those of the visual alone condition (controlling for auditory effects on visual salience). Auditory-visual stimuli in condition 3 were responded to faster than visual or auditory targets alone, but this benefit was significantly reduced for

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auditory-visual stimuli equated for visual detectability (condition 4; p=.01) suggesting that the redundant-target effect is partly driven by auditory enhancement of visual salience in addition to multisensory integration.

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43.515 Supramodal number-selective representation in human left parietal lobe at 7T

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The ability to apprehend the number of elements in a set is shared by humans (including infants) and other primates. This ability seems to be represented by specialist groups of neurons in bilateral IPS in both humans and monkeys. What remains controversial is whether these regions serve a unitary neuronal basis for all forms of numerical representations, i.e., independent of the sensory modality (e.g. visual and auditory numbers) present. To examine whether numbers are represented independently from different sensory modalities, we use fMRI adaptation paradigm and present the first ever study of cross-modal number processing where the brain is imaged at 7T to generate both higher resolution, higher signal-to-noise ratios and higher BOLD contrast sensitivity. The evidence we present indicates there are both common and distinct neural responses to visual and auditory numbers, depending on the hemisphere of human parietal lobes. Number-selective neurons represent numbers from visual and auditory modalities in a supramodal manner in the left IPS, while those neurons in the right IPS are more modality specific. Moreover, there exists an asymmetry in these supramodal responses for the order of the two consecutive crossmodal numbers present within a trial. A strong adaptation effect was observed for an auditory number following a visual number, but not vice versa. Further behavioral experiment using priming paradigm, with visual stimuli prior to auditory targets or auditory stimuli prior to visual targets, shows similar asymmetry as observed in fMRI studies. We infer that the asymmetry might be due to a dominant representation of visual numbers over that of auditory numbers.

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43.516 Congruent Auditory Input Can Bias Bistable Vision without Voluntary Attentional Control

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Prior research presents conflicting evidence as to whether the ability of congruent auditory information to resolve visual ambiguity is dependent on voluntary attentional selection of congruent stimuli (Van Ee et al., 2009; Alais & Parker, 2006). We used novel speech stimuli to test whether audiovisually congruent visual stimuli were dominant in binocular rivalry even when subjects were not aware which visual stimulus was associated with the auditory stimulus, effectively barring subjects from deliberately selecting the congruent stimulus with attention (verified post-experimentally). The stimuli were derived from prior research demonstrating that speech sounds distort the visual perception of ellipses towards associated mouth shapes: hearing a /wee/ sound causes increased perceived horizontal elongation of a circle, whereas hearing a /woo/ sound produces vertical elongation (Sweeney et al., 2012). In the current study, subjects were presented dichoptically with two animations of ellipses that each continuously elongated horizontally and vertically in alternation. The stimuli presented to each eye differed only in that they (a) were luminance-matched red or green, and (b) alternated counterphase such that, at any time, the horizontal extension of one ellipse was equal to the vertical extension of the other. Simultaneously, repeating voiced syllables /wee/ and /woo/ were played in synchrony with the visual stimuli so that, throughout each trial, there was a shape-sound correspondence with the ellipses presented to only one of the eyes. Subjects were instructed to continuously report which changing ellipse was perceptually dominant throughout the trial, ignoring the auditory stimuli as distracters. Each subject participated in sixteen 32-second trials, counterbalanced for color of congruent stimulus and the eye to which it was presented. Perceptual dominance durations for the audiovisually congruent stimuli were significantly longer than those for the incongruent stimuli. These results demonstrate that phonologically congruent auditory input can bias bistable vision in the absence of voluntary attentional control.

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43.517 Comparisons of temporal frequency limits for cross-attribute binding tasks in vision and audition

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The speed of temporal binding of sensory signals, processed in parallel, can be psychophysically estimated from a critical temporal frequency beyond which observers cannot discriminate the phase relationship between two oscillating stimulus sequences. Fujisaki and Nishida (2010) showed that the temporal limit for visual cross-attribute binding tasks, as well as cross-modal binding tasks, is about 2.5 Hz regardless of attribute combination. Last year, we examined the temporal limits of two auditory cross-attribute binding tasks, and found that the limit of one condition was significantly higher than 2.5 Hz (Kanaya et al., 2012, VSS). However, this experiment did not completely exclude sensory cues produced by peripheral interactions of two auditory sequences. The present study therefore measured the temporal binding limits within and across three auditory attributes (frequency (FREQ) and amplitude (AMP) of a pure tone, and fundamental frequency (F0) of a band-limited pulse train) using stimulus parameters carefully selected to eliminate signal interactions within peripheral channels. The same participants also performed a visual binding task (color-orientation). Results showed that the temporal limits for auditory within-attribute binding tasks were 3.9 (FREQ-FREQ), 5.4 (AMP-AMP) and 3.4 Hz (F0-F0). The limits for auditory cross-attribute binding tasks were 4.0 (FREQ-AMP), 3.6 (FREQ-F0) and 3.3 Hz (AMP-F0), whereas the limit of the visual cross-attribute binding task remained close to 2.5 Hz. Therefore, even under conditions excluding peripheral interactions, the temporal limit obtained with auditory cross-attribute binding tasks can be higher than that of vision. Our findings are consistent with the hypothesis that, while cross-modal and visual cross-attribute binding tasks reflect a high-level attribute-independent binding mechanism, auditory cross-attribute binding tasks, at least those we have tested, can also reflect sensory processing stages earlier than the high-level binding mechanism because neural processing for different auditory attributes is not segregated as clearly as that for different visual attributes.

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43.518 Sound delay in audiovisual events can signal object depth

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The slower arrival time of sound relative to light varies linearly with the distance of an audiovisual event and can potentially be used as reliable cue to depth. Here, we aimed to determine if sound delay in audiovisual events can influence visual judgments of distance. We hypothesized that a given visual event paired with delayed sound would be perceived as being further away than when paired with synchronous sound. Using a 2IFC task, participants judged the distance of two stereoscopically presented random dot clouds in a fixed 3D volume (250ms duration, 1-1.5 ms ISI). In one interval the cloud was paired with a synchronous sound, while in the other, the sound was delayed by 80 ms relative to the visual stimulus onset. By varying the disparity of the dots, the 'cloud' presented in the second interval was stereoscopically shifted either toward or away from the participant relative to the first cloud. Task difficulty was controlled by the percentage of dots that coherently shifted in depth, ranging from 0% (random dispersion of dots) to 100% (fully coherent shift). When the delayed sound was presented in the second interval, participants showed a bias towards perceiving the stimuli as shifting away from the observer. The opposite pattern occurred when the delayed sound occurred in the first interval. By comparing congruent and incongruent audio-visual pairings, we found a trend for participants to be more precise when sound delays were congruent, with the direction of the visual depth shift. These findings reveal that sound delay in audiovisual events can be used when making distance judgments—a task previously thought to be solved only visually. Evidently, sound delays modulate visual depth perception and possibly provide a previously unknown depth cue.

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43.519 The Development of Cross-Modal Attention: When can a sound impair visual detection?

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Previous studies in adults suggest that auditory information can influence the detectability of visual information (for example, Stein et al., 1996; Lovelace et al., 2003; Oodgard et al., 2003; 3004). Little is known regarding the development of such influences. Here we investigate whether auditory cues can alter visual detectability in 3- and 6-month old infants. We used forced choice-preferential looking (FPL) to obtain contrast detection thresholds for a visual stimulus, a square (11x110, centered 150 left or right of monitor center. The visual stimulus fluctuated in luminance at 1 Hz, under four different auditory conditions: (1) IP: an auditory stimulus, white noise modulating in loudness at 1 Hz, fluctuated in-phase with the visual stimulus, (2) OP: the auditory stimulus fluctuated out-of-phase with the same visual stimulus, (3) NS: no auditory stimulus was presented, or (4) CS: a constant auditory stimulus was presented. The visual stimulus was presented at one of five contrasts, randomized across trials. Threshold was defined as the contrast yielding 75% correct performance in the FPL task. For each subject, visual thresholds were obtained for two of the four possible conditions, over the course of 2-3 days. If synchronized auditory information enhances visual detection, we expect lower contrast thresholds for the IP condition relative to the other conditions. Our data in 3- and 6-month-olds show that synchronized auditory information can worsen the detectability of visual stimuli near threshold. Such a counter-intuitive finding can be explained by the reallocation of cross-modal attention. If attention is a limited resource across modalities, a highly salient auditory stimulus can redirect attention away from a near-threshold visual stimulus, worsening visual detectability the most when visual and auditory information are changing in the same way over time (IP).

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43.520 **Using the population receptive field method to assess auditory frequency tuning in early blind individuals** Elizabeth Huber[1](e-huber@uw.edu), Jessica M. Thomas[1], Ione Fine[1]; [1]Department of Psychology, University of Washington

Introduction: Individuals with early onset blindness have enhanced auditory abilities that are associated with changes in both auditory and occipital cortex. In auditory cortex, alterations of the amplitude and extent of responses have been noted (Elbert et al. 2002; Stevens and Weaver, 2009). In occipital cortex, early blind subjects show cross-modal responses to a wide range of auditory stimuli across multiple visual areas (Roder et al., 2002; Poirier et al., 2005; Lewis et al., 2010). Methods: We carried out tonotopic mapping in auditory and occipital cortex in 4 early blind and 4 sighted controls using functional magnetic resonance imaging. Our stimuli were pure tones ranging from 88 to 8000 Hz, presented in ascending, descending, and randomized sequences during separate runs, based on methods used by De Costa et al. (2011). Data were analyzed using an adaptation of the population receptive field technique developed by Dumoulin and Wandell (2008) for retinotopic mapping. Our model treats the aggregate receptive field underlying each voxel's response as a one-dimensional Gaussian function of frequency. This technique provides an estimated sensitivity function for each voxel with a given center, or preferred frequency, and standard deviation, or tuning bandwidth. Results: We obtained consistent and reliable tonotopic maps within auditory cortex for both subject groups. It remains to be determined with additional subjects whether tuning bandwidth and/or the size of PAC might differ across blind and sighted subjects. We also observed cross-modal responses to pure tones in early blind, but not sighted, subjects. These frequency selective responses to pure tones in occipital cortex of blind subjects were as robust as PAC responses. In contrast to responses in PAC, the majority of occipital responses were preferentially tuned to frequencies within a 1000-1500 Hz range. This range is associated with a variety of behaviorally relevant sounds.

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43.521 **The effect of body orientation on the perception of depth**
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Models of spatial perception typically assume no contribution of vestibular information to the perception of distance despite the importance of updating object distances during motion and expected variations in the distance to the ground plane during head tilt. To investigate the possible contribution we investigated depth perception with different body postures but with visual context cues constant. Experiments were conducted in the York University Tumbled Room, a realistically decorated room (8′ x 8′ x12′) oriented orthogonal to gravity, and in a normally oriented control room. The length of a visual line, projected onto the far wall by a laser, was compared to a tactile reference rod. An adaptive psychometric procedure was used to control the length. Ten observers were tested in an upright posture with respect to each room binocularly and monocularly with the room visible, and binocularly with only the line visible. The line length judged as equal to the reference rod was significantly longer (p=0.015) in the tumbled room by 108.8% ± 5.7% than in the control room. The effect was larger during monocular viewing (p<0.01, 113.6% ± 9.6%) but went away in the dark. The longer line length required to appear equal to the reference rod when subjects were on their backs suggests that, as in the moon illusion, it appeared closer (up to 74% of the actual distance). By keeping the visual context constant, this is the first demonstration that posture has a direct effect on perceived size and, by implication, distance. That the effect was largest with monocular viewing suggests a moderating effect of stereopsis (as in the moon illusion). The fact that the effect disappears in the dark suggests that it is due to a conflict between visually and gravitationally defined reference frames rather than directly due to posture relative to gravity.

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Attention: Reward, motivation, emotion

Monday, May 13, 8:30 am - 12:30 pm

Poster Session, Vista Ballroom

43.522 **ERPs suggest that visual feedback processing in decision-making is modulated by subjective perception of outcome**
Faisal Mushtaq[1](ps06fm@leeds.ac.uk), Richard Wilkie[1], Mark Mon-Williams[1], Alexandre Schaefer[2]; [1]Institute of Psychological Sciences, University of Leeds, UK., [2]Wolfson Research Institute, University of Durham, UK.

Introduction: Visuomotor strategies come close to maximising expected gain but economic preference tasks indicate that people often cognitively misrepresent the probability of outcomes (Kahneman & Tversky, 1972; Trommershäuser et al., 2008). One explanation for the cognitive biases is that individuals evaluate outcomes relative to prior reward probability contexts rather than the current objective value of the feedback. The present study examined the neural correlates of relative changes in reward probability. Methods: We measured the visual feedback-related negativity (FRN) in a gambling task. The FRN is an electrophysiological correlate of attention-related outcome processing, which differentiates between rewards and punishments (Gehring & Willoughby, 2002). On each trial, participants decided between a risky and a safe option, presented as different coloured shapes. Each gamble was accompanied with visual feedback. The reward probability (RP) associated with gambles was manipulated so there were four different blocks: (i) 'Win Block' (WB) with a positive context of 80% RP; (ii) 'Loss Block' (LB) with a negative context of 20% RP; (iii) 'Post-Win' (PW) block of 50% RP occurring immediately after a WB; (iv) 'Post-Loss' block of 50% RP occurring immediately after a LB. Results: 50% RP environments yielded different FRN patterns according to whether they reflected a relative improvement or decrement from the previous condition. This is consistent with the idea that outcome-monitoring processes are influenced by relative states. The pattern of FRN activity in the PL and PW blocks mirrored activity in the WB and LB respectively; suggesting the FRN is driven by subjective perceptions of outcome. Conclusions: The data indicate that relative changes in reward probability from previously learned contexts can bias our evaluation of the valence of current outcomes. These neurophysiological data shed some light on the factors that produce differences between visuomotor and cognitive strategies in decision-making.

43.523 **Task information overrides attentional capture by reward-associated stimuli** Beth A Stankevich[1](bstankevich@ucdavis.edu), Kyle Pugher[2], Joy J Geng[1,2]; [1]Department of Neuroscience, UC Davis, [2]Department of Psychology, UC Davis

Reward is a powerful motivator that has robust effects on behavior. Recent work has shown that rewarded locations and stimulus features capture attention, even when the reward information is no longer task-relevant (Kiss, Driver, Eimer, 2009; Andersen, Laurent, and Yantis, 2011; Theeuwes and Belopolsky, 2012). These studies suggest that reward-associated information is automatically assigned high attentional priority. However, few of these tasks used experimental paradigms in which it would be beneficial to suppress attention to the reward-associated stimulus. We used a variant of the Posner cueing paradigm in which bilateral colored circles were presented on each trial. Subjects first learned to associate each color with an amount of monetary reward. Critically, in Exp. 1, we introduced competition for attentional priority by gradually increasing the probability

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of the target in one location (e.g., proportion of target on the right vs. left: 0.5:0.5, 0.6:0.4, 0.7:0.3, 0.8:0.2, 0:1). The location of the high reward color was always random. The results demonstrated an interaction between probability and reward value. Initially, performance was better (i.e., shorter RTs and higher accuracy) for targets in the high-reward location, but this pattern reversed as the strength of the spatial probability increased. The identification of a point of subjective equality (PSE) between the two biases suggested that the allocation of attention to rewarded features was counterbalanced by spatial expectancies. In Exp. 2, we tested whether this effect extends to task-irrelevant bottom-up saliency defined by luminance. In contrast to Exp. 1, subjects had shorter RTs and higher accuracy to targets in the high reward color regardless of the perceptual saliency of the exogenous cue. Together these results indicate that while reward is a powerful bias on spatial attention, there is a push-pull relationship between reward and other sources of task-relevant information. In contrast, reward-associated information appears to be prioritized over task-irrelevant saliency.

43.524 **The Role of Predictable and Unpredictable Reward in the Control of Attention**

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Stimuli previously associated with reward involuntarily capture attention (Anderson, Laurent, & Yantis, 2011, PNAS; Anderson & Yantis, in press, AP&P). One possibility is that this value-driven increase in attentional priority reflects the learned association between prior targets and the receipt of reward. Another possibility is that motivating visual search with reward enhances perceptual learning for former targets. To adjudicate between these two accounts, we measured the degree to which previous-target-colored stimuli capture attention following differing target□reward contingencies. Each of three experiments began with a training phase in which participants received monetary rewards for correctly reporting a color-defined target in visual search. In Experiment 1, the target color remained constant across trials during training, although the magnitude of reward received for a correct response varied unpredictably. In Experiment 2, target color varied unpredictably between red and green, but the reward for a correct response remained constant. In Experiment 3, target color again varied unpredictably, but one color was associated with a greater reward than the other when correctly reported. Thus, participants received rewards for locating color-defined targets in all experiments, but only in Experiment 3 did the target color accurately predict the amount of reward. Following training, participants in all experiments completed a test phase in which stimuli carrying the color of a previously rewarded target occasionally appeared as a task-irrelevant distractor. Former-target-colored stimuli captured attention only in Experiment 3, when target color predicted reward. This finding argues against a motivated perceptual learning account of value-driven attentional capture: merely rewarding the performance of visual search was not associated with a persistent involuntary orienting of attention toward the previous target feature. Instead, our data suggest that value-driven attentional capture is mediated by mechanisms of reward learning, such that attention is involuntarily drawn to stimuli that have been learned to predict available reward.

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43.525 **Reward-based Transfer from Bottom-up to Top-down Search Tasks**

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Much of the recent evidence suggests that reward modulates bottom-up as well as top-down attentional selection. Interestingly, this modulation persists within the same type of task even when reward contingency is no longer relevant. It remains unclear whether the effect of learned reward contingency is transferred across different modes of attention. Successful transfer would provide evidence for an integrated reward-based priority map used for both top-down and bottom-up attentional guidance. Here, we investigate whether reward-based contingency learned within a context of a bottom-up search task is transferred to a subsequent top-down search task. To elucidate how a reward-based priority map is constructed, we also examine whether the reward-based transfer influences search efficiency by enhancing target salience, or changing distractor filtering, or both. Results showed that a biased reward schedule modulated search efficiency in a pop-out search task, and that this modulation effect was transferred to a conjunction search task with an unbiased reward schedule. Compared to baseline, search for a target containing a feature previously associated with higher reward became more efficient. Additionally, a direct relationship was observed between the magnitude of reward effects in the pop-out and conjunction search tasks, giving further evidence for reward-based transfer across different types of attentional control. We also show that reward history influences search efficiency by both enhancing target salience and changing distractor filtering. Interestingly, previously rewarded distractors either enhance or interfere with search efficiency depending on what critical feature they share with the target (color or orientation). A direct relationship was observed between the magnitudes of reward-based target enhancement and distractor interference, indicating that a reward-based priority map is influenced by values associated with both target as well as distractors. These results strongly suggest that an integrated priority map, based on reward information, guides both top-down and bottom-up attention.

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43.526 **Investigating the Temporal Dynamics of Rewarded Stimuli in an RSVP Task**

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When certain stimuli are associated with reward, they develop attentional priority and capture attention. Additionally, Theeuwes, Belopolsky, and Van der Burg (2012) showed at VSS last year that highly rewarded stimuli have a modest temporal processing enhancement. The current project explored the temporal dynamics of attentional prioritization within the context of an attentional blink (AB) paradigm. Participants took part in both a training phase and a test phase. During the training phase, the colors red and green were rewarded with points and sound effects, an established paradigm that produces attentional capture for rewarded colors (Miranda & Palmer, 2012). During the test phase, participants took part in an AB task in which they were asked to identify two colored letter targets, T1 and T2, in a stream of 20 otherwise white letters. One third of the T1 letters had previously been associated with high reward, one third had been associated with low reward, and one third had not been associated with reward. No T2 letter colors were previously associated with reward. We hypothesized that highly rewarded colors presented at T1 would reduce the AB magnitude for T2 items due to faster processing of stimuli with attentional priority. We observed a robust AB, though there were no significant differences in the time course of T2 detection accuracy (given T1 correct) between the three reward conditions. However, there were reliable differences in accuracy of identifying T1. T1 accuracy was significantly higher for colors associated with both high and low reward compared to colors not previously associated with reward. Following Chun & Potter's (1995) AB model, this indicates that attentional prioritization of T1 items may not move them through the attentional bottleneck fast enough to alleviate the AB for T2 items. We are currently investigating the effects of rewarded T2 colors on the AB.

43.527 **Learned Reward Association Acts as "Template for Rejection" in Visual Search Task**

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Recent literatures have demonstrated that previously learned reward association modulates attentional allocation to current visual input. The manner in which attention is automatically guided by reward-associated item fits well with the benefit of stored "attentional template". However, whether the reward-associated item can be used to guide attention away as "template for rejection" remains unclear. To test this possibility, we first established reward-color association, and then tested the effect with a cued visual search task (Experiment 1). Search display consisted of a ring of twelve circles, each embedded with an oriented bar. For each trial, the circles from a half ring (left or right) were set to be one color and the other half in another color. Observers' task was to search for uniquely oriented bar. They were instructed to exclude the circles in pre-cued color during search as target never appeared in these circles. The results showed significantly faster search RT for the pre-cued color associated with high reward than those with low reward ($p<0.01$) or non-reward ($p<0.01$), indicating a faster rejection of the high reward-associated color. To eliminate the contribution of spatial attention to the observed effect, we distorted the color symmetry of the search display (Experiment 2). The new search display consisted of eight Landolt-C in two colors with equal number. Similar pattern of results was obtained by instructing observers to exclude the precued non-target colors. Moreover, a memory test at the end of each trial verified that such rejection did not impair the representation of the precued color in working memory. Interestingly, the effect remained when we rendered the pre-cued color as search target and the reward-associated colors were never cued or explicitly rejected (Experiment 3). Our results suggest a flexible role of reward association in facilitating visual search performance by modulating attentional weights towards rewarded items.

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43.528 Learned Emotional Associations Influence Visual Processing, Eventually

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Emotional stimuli, such as snakes or angry faces, are prioritized during visual processing, often at the expense of other task-relevant visual information. Here we investigated whether neutral stimuli that have been associated with emotional characteristics can exert a similar influence on visual processing, and where in the time course of processing such effects of emotional knowledge, if present, emerge. In Experiment 1, participants learned to associate negative or neutral characteristics with a set of neutral face images. These faces then served as the first target in an attentional blink paradigm. On each trial 18 furniture and 2 target (T1 and T2) images were presented for 68ms each. T2 always lagged T1 by 3 (210-ms), 5 (350-ms), or 9 (630-ms) images. Participants indicated whether T1 (either a learned or novel face) was old or new and whether T2 (a watch) contained numbers or non-numbers. Faces with learned negative associations elicited a greater blink for subsequently presented targets, but only when T2 lagged by 350 ms ($p<.001$). In Experiment 2, similar training and RSVP paradigms were utilized to investigate the time course of accessing emotional knowledge. Each RSVP trial contained a target face (either trained or untrained) and ended with a word or non-word to which participants made a speeded lexical decision. Responses to affectively congruent words (i.e., a negative word following a face associated with negative characteristics) were faster than to affectively incongruent words. However, consistent with Experiment 1, this only occurred with a face-word lag of 350-ms ($p=.05$). Together, these findings suggest that (emotional) conceptual knowledge can produce stimulus prioritization and costs for other subsequently presented stimuli providing there is sufficient time to access the conceptual representation. These results suggest that the prioritization of emotional stimuli can occur via a flexible evaluation mechanism that incorporates higher-order information during visual processing.

43.529 Rapid self-tagging to sensory stimuli: Functional and neural effects

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The assignment of personal social significance to a stimulus is a basic human capacity that is currently poorly understood. Here we present evidence showing a robust self-prioritization for this assignment process using a self conditioning procedure in which we 'tag' a neutral shape with self-relevance. Participants were instructed to associate three neutral geometric shapes (circle, square, and triangle) with three people, one with themselves, one with one of their best friends, and one with an unfamiliar other. After the instruction, they had to judge whether subsequent label–shape pairings were matched. Across a series of experiments participants showed a benefit for establishing self conditioning relative to conditioning related to other people, on both response times and perceptual sensitivity. fMRI data revealed that rapid self-tagging responses were associated with enhanced activity over brain regions linked to self representation (the ventro-medial pre-frontal cortex, vmPFC) and to sensory-driven attentional control that is associated with processing social information (the left posterior superior temporal sulcus, LpSTS). In contrast, associations formed to other people recruited a dorsal fronto-parietal control network. Effective connectivity analyses showed that the vmPFC and the LpSTS were functionally coupled and that stronger projections from the vmPFC to the LpSTS for self-related stimuli predicted greater behavioral biases to the self. Self-conditioning to sensory stimuli produces a rapid neural change by coupling self-representations to brain regions modulating sensory-driven attentional control.

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43.530 When actions have no consequences: Rewards in visual search and the role of contingencies

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Hickey, Chelazzi & Theeuwes (2010; 2011) have reported an intriguing effect of reward upon visual search performance. In an odd-one-out paradigm a diamond target appears in an array of circles (or vice versa). A salient color singleton is presented on some trials, while on other trials all items are uniformly colored. Observers are rewarded for correct responses with randomly varying 'high' or 'low' monetary values. Since the reward is random, it is not contingent upon any aspects of the display. Hickey et al. found that responses to targets following 'high' reward trials are speeded when the color scheme of the previous trial is repeated while a color scheme swap resulted in an inhibitory effect. In two experiments, we tried to expand on these findings. We tested whether the results would generalize to identical contingencies and variables, but different stimulus materials (colored Gabors, rather than shapes). Observers were tested on singleton versus no-singleton trials varying within blocks or run in separate blocks. Reward had no effect on performance at all. Observers might as well have ignored reward altogether. This was true of both mixed and blocked conditions. This failure to replicate does not necessarily come as a surprise, however. The boundary conditions of non-contingent reward priming may be very subtle and depend heavily on an observer's attitude towards the task. A corollary of a non-contingent reward schemes is that the strategy to ensure maximum monetary pay-off is to maximize accuracy in any condition, which may overshadow beneficial and/or inhibitory effects of reward values. We discuss how task contingent reward schemes may be better suited to reveal the functional interplay of reward and visual attention.

43.531 Dissociating the Effects of Reward on Sustained Attention to Visual Scenes

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While reward is known to be a powerful and lasting force on spatial attention, its effects on sustained visual attention are not well understood. Specifically, it is unclear how reward affects dissociable aspects of sustained attention, including accuracy, response consistency (i.e., reaction time variability), and the decrement in these measures over time. The current study further examines reward and sustained attention by 1) using the gradual onset continuous performance task (gradCPT), which is sensitive to these multiple aspects of sustained attention (Esterman et al. 2012); and 2) manipulating reward with instructions that better performance would result in earlier completion of the task. In the 10-minute task, participants view scenes that gradually transition from one to the next, and are instructed to respond to city scenes (90%) and withhold for mountain scenes (10%). After completing several baseline gradCPTs with no reward, participants performed a final gradCPT with either standard instructions or instructions that the task could be completed sooner based on better performance. Though performance on the baseline gradCPTs did not differ between groups, the participants in the reward condition demonstrated improved response inhibition to mountain scenes and showed decreased reaction time (RT) variability to city scenes. Despite these reward-related performance improvements, both groups displayed parallel decrements in performance over time. This demonstrates that reward can improve response control and decrease high-frequency attentional fluctuations, suggesting that failures of these processes may be due to lack of effort or motivation. On the other hand, the decrease in performance over time failed to be modulated by reward, suggesting that the rate of depletion of cognitive resources is less malleable by motivational factors. These data indicate that dissociable mechanisms contribute to fluctuations in sustained visual attention.

43.532 Visual orienting biases during reward learning

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Recent studies indicate that stimuli with reward associations are especially effective at capturing attention and at gaining access to visual working memory. However, these effects generally show large individual variability. We investigated whether this stems from individual differences in visual orienting during learning, a well-known characteristic of animals undergoing Pavlovian conditioning (Boakes, 1977). Specifically, some animals (cue-trackers) predominantly orient toward visual cues that precede reward availability, whereas others (goal trackers) predominantly orient toward reward locations (goal box). Although all animals show learning, the cue-trackers produce dopaminergic striatal responses to cues similar to those made in response to actual rewards; goal-trackers show no such cue-induced responses. Perhaps value-based attention capture in humans stems from cue tracking during learning. Mimicking animal studies, we monitored the eye movements of adults learning to associate coloured shapes (cues) with monetary rewards. In blocks of trials, cues and rewards appeared reliably in different locations with each location marked by a checkerboard during inter-trial intervals. Eye movements during this period were used to index cue- versus goal-tracking behaviour. Cues appeared briefly; then participants pressed a key to reveal their reward. After each block, each cue was rated for "luckiness" to provide an explicit learning measure. Key press speed provided an implicit measure of learning. As expected, both explicit and implicit learning in all participants was observed. Cues with the highest expected value produced the highest ratings and the fastest key presses. Although the majority of participants showed consistent fixation biases toward cue versus goal locations during the inter-trial interval, we observed substantial individual differences in cue/goal biases, showing that human variation in orienting during learning may mirror effects found in animals. We anticipate that this novel method of quantifying visual orienting biases during associative learning may usefully predict the strength of value-driven attention capture measured subsequently.

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43.533 **Irrelevant emotional content in working memory biases visual attention** Jane Raymond[1](j.raymond@bham.ac.uk), Anthony Brennan-Craddock[2]; [1]School of Psychology, University of Birmingham, [2]School of Psychology, Bangor University

Some Previous studies have reported that non-emotional, irrelevant information held in visual working memory (WM) can bias selective attention. We asked whether irrelevant emotional content in WM might similarly modulate putative attentional biases to threat stimuli in a simple search task where emotional content is irrelevant. We created a WM 'sandwich' task comprising three displays (D). First, (D1) a single face photo (one of 3 possible faces) expressing either anger or happiness was presented (500 ms). Then, 1200 ms later, (D2) two schematic faces (one happy, one angry), each with a short central vertical or horizontal line ('nose') and a different coloured frame were presented (200 ms). Lastly, (D3) a menu of three neutral face photos was shown. The WM task was to remember D1's identity and to select it correctly from D3. The search task (presented during WM maintenance) was to report (by speeded key press) whether the 'nose' in the target schematic face (pre-designated by frame colour) was vertical or horizontal. Target faces were equally likely to be happy or angry. Threat biases predict faster response times (RT) to D2 when targets are angry versus happy. A control group viewed the same display sequence but instead identified D1 immediately (prior to D2) and made no response to D3, eliminating the WM component but controlling for emotional priming of D1 on D2. (N=28 in each experiment.) When a happy face identity was stored in WM, search RT revealed the expected threat bias (17 ms, $p < .02$). However, when an angry face identity was stored in WM, this bias was eliminated showing that emotional WM content can modulate attentional priorities. The control group showed faster RTs than the WM group, no effect of emotional priming, and no threat bias. Positive WM content appears to enhance attentional bias to threat.

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43.535 **Perceptual gating of value-driven attentional capture** Lihui Wang[1](lihui.wang28@gmail.com), Hongbo Yu[1], Xiaolin Zhou[1,2]; [1]Center for Brain and Cognitive Sciences and Department of Psychology, Peking University, Beijing, China, [2]Key Laboratory of Machine Perception (Ministry of Education), Peking University, Beijing, China

Previous research demonstrated that associating a stimulus with value (e.g., monetary reward) can increase its salience and induce a value-driven attentional capture when it becomes a distractor in visual search (Anderson et al., 2011). Here we investigate to what extent this value-driven attentional capture is affected by the perceptual salience of the stimulus. We manipulated the perceptual salience of the stimulus associated with value and the type of value attached to the stimulus. We showed that a color previously associated with monetary gain or loss impaired subsequent search for a unique shape target (Experiment 1), but a shape that was previously associated with gain or loss did not affect search for a unique color target (Experiment 2), indicating that the associative learning of value and the effect of value-driven attentional capture are modulated by the perceptual salience of a stimulus. The value-based attentional capture reoccurred when the shape distractor was associated with biologically aversive (pain) stimulation (Experiment 3), indicating that when the value is significant enough to an organism it can render a perceptually less salient stimulus capable of capturing attention in visual search. These results suggest that perceptual salience modulates the value-based attentional capture and the extent of value information capturing attention depends on the biological significance of the valued.

43.536 **Inhibition of return to emotional faces** Yuanyuan Zhao[1](Yuanyuan.a.zhao@gmail.com), Jing Tian[1], Lei Lei[1], Shihui Han[1]; [1]Peking University

Inhibition of Return (IOR) refers to a phenomenon that reaction times are slowed to a target that appears at a previously attended location. To investigate whether the mechanism of IOR is modulated by emotional contents of stimuli, the current study examined IOR to angry, happy and neutral faces. The speed-accuracy trade-off (SAT) function was measured to assess IOR in terms of sensitivity and processing time related to targets. Participants were required to discriminate gender of faces presenting on the cued or uncued locations under various response speeds controlled by experimenter. We have three findings: Firstly IOR to neutral faces was associated with shifts in response criterion, in line with our previous findings (Zhao et al. 2011). Secondly, IOR to emotional (angry and happy) faces was evident only at an early stage of target processing. Moreover, it was eliminated at a later stage of target processing and was reversed into a facilitation effect. According to the evolutional view, the arousal state decreased the response criterion to emotional faces which are interesting and important to us. Finally, perceptual sensitivity of gender discrimination was decreased to angry compared to neutral faces and the levels of decrement were significantly correlated to participants' state-trait anxiety. Negative stimuli may increase the attentional demand as they might threat our chance of survival. This may lead to less attentional resource available for the discrimination task and in turn performance was impaired. In conclusion, the findings extended the evidence of IOR reflecting a criterion shift from low-level signal (e.g. '+' or 'x') to high-level socially relevant stimuli such as neutral faces. Furthermore, it suggests that the arousing dimension of emotion interacted IOR in the response level while the valence dimension of emotion affected discrimination in the attentional level.

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43.537 **The Role of Feature Salience in Emotion-induced Blindness** Steven B. Most[2,3](most@psych.udel.edu), Sage Boettcher[1], James E. Hoffman[2]; [1]Harvard Medical School & Brigham and Women's Hospital, [2]University of Delaware, [3]The University of New South Wales

Emotion-induced blindness (EIB) refers to impaired awareness for items appearing soon after an irrelevant, emotionally arousing stimulus. In previous research we analyzed the mechanisms responsible for EIB using event-related brain potentials (ERPs). Participants searched rapidly presented streams of pictures (landscapes and cityscapes) for a target, which was a scene picture rotated 90 degrees left or right. Each stream also contained an irrelevant "distractor" picture that could be emotionally negative (dangerous animals, mutilated bodies, etc.) or neutral (people and animals in nonemotional settings). When the irrelevant negative picture preceded the target by two pictures, target discrimination was severely impaired. A smaller impairment emerged following neutral distractors. We discovered two ERP components related to the magnitude of this suppression: the N2 and the Pd. The N2, which is thought to reflect attentional engagement, was larger in response to Negative than to Neutral distractors, while Scenes produced no discernible N2. Thus, the amplitude of the N2 elicited by a distractor was related to its ability to suppress a subsequent target. A similar relationship was observed for the Pd component, which follows the N2 and is thought to reflect attentional disengagement. The current research addresses the following question: Are these differences between neutral and negative distractors due to differences in valence or to uncontrolled differences in physical salience? We examined this issue by using pairs of neutral and negative distractor pictures that were chosen and/or manipulated to maximize their physical similarity to each other. Although this manipulation eliminated the difference in N2 amplitude, negative distractors continued to cause greater EIB than did neutral pictures, and they continued to elicit larger Pd components. These results suggest that the N2 may be related to physical salience but that this factor does not fully account for perceptual impairments caused by emotionally negative, relative to neutral, distractors.

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43.538 **Dissociating stimulus visibility and fear related processing using metacontrast masking** Philipp Hintze[1](philipp.hintze@uni-muenster.de), Markus Junghöfer[1], Maximilian Bruchmann[1]; [1]Institute for Biomagnetism and Biosignalanalysis, University of Muenster

In our study, we took a correlational approach to disentangle the relation between stimulus awareness and neurophysiological markers of fear related processing, using metacontrast masking to manipulate stimulus visibility in consecutive steps (by increasing the SOA between target and mask). The function of visibility in metacontrast masking is U-shaped with

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high visibility at low SOAs, a decline in visibility with increasing SOA to a minimum at around 50ms, followed by a gradual increase in visibility at SOAs of 100ms and longer. The descending branch of this U-shaped masking function up to its minimum allows for a double dissociation between stimulus visibility and the time of uninterfered target processing of the target stimulus: Visibility decreases while the time of uninterfered target processing increases with increasing SOA. One of two physically identical target gratings was paired with an aversive startle burst in a trace conditioning protocol. We compared the differences in the visual evoked potentials of conditioned and neutral stimuli at three SOAs on the descending branch of the masking function. We find that, while detectability and discriminability of the target stimuli decrease with increasing SOA as expected, the difference in the visual evoked potentials increases with increasing SOA. This double dissociation between stimulus visibility and fear related processing is the soundest possible evidence for the hypothesis that fear conditioning is not depending on stimulus awareness. As metacontrast masking is assumed to be caused by feed-forward signals of the mask interfering with recurrent activity of the target, we assume affective processing to be strongly reliant on feed-forward information: The longer the feed-forward signal of the target is available without interfering feed-forward signals of the mask, the stronger aversively conditioned and neutral stimuli diverge.

43.539 **Neural Mechanisms of Value-Driven Attentional Capture**

Brian A. Anderson[1](bander33@jhu.edu), Patryk A. Laurent[1], Steven Yantis[1]; [1]Department of Psychological & Brain Sciences, Johns Hopkins University

Goal-driven and stimulus-driven factors interact to determine the attentional priority of stimuli. A wealth of research demonstrates that goal-driven attention is subserved by a frontal-parietal network of brain regions, and stimulus-driven attention by a temporal-parietal network. Recently, we showed that stimuli previously associated with reward capture attention independently of their physical salience and goal-relevance (Anderson, Laurent, & Yantis, 2011, PNAS). This suggests a value-driven representation of attentional priority that may be computed outside of the goal-driven and stimulus-driven attention networks; however, the neural basis of value-driven attentional capture remains unexplored. In the present study, we measured brain activity using fMRI while participants carried out a pair of visual search tasks. They first completed a training phase in which each of two color stimuli differentially predicted a monetary reward; these same color stimuli later served as irrelevant distractors in an unrewarded test phase comprising visual search for a shape singleton target. Replicating our previous behavioral findings, we found that response time in the test phase was slowed by the presence of a previously reward-associated distractor. Neuroimaging data showed that valuable distractors elicited an increased stimulus-evoked response in contralateral regions of extrastriate visual cortex and caudate tail. The caudate tail, part of the striatum, is known to play an important role in reward processing; it has not been implicated in either goal-driven or stimulus-driven attention, but is well suited to mediate the feature-based value-driven control of attention. Our results suggest that representations of visual stimuli in the caudate tail are modified by reward learning; this in turn increases their effective salience in early visual areas of extrastriate cortex. This striatal-extrastriate locus of attentional control indicates a possible neural substrate for a key value-driven attention network.

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43.540 **The Neural Response to Visual Insight and Humor**

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The pattern of neural and behavioral activation to a visual image can differ markedly based on the image's interpretation. Subjects were scanned while they viewed simple drawings that were uninterpretable until a description was presented that provided either: a) a solution to an unusual view ("insight") of a single object, b) a highly humorous interpretation of the image that linked remote concepts, or c) a (control) surface description of the drawing's shape that elicited neither insight nor humor. Biederman & Vessel (2006) proposed that activity in the latter stages of the ventral pathway that are rich in μ-opioid receptors and project to dominergic classical reward pathways could account for spontaneous visual selectivity and pleasure. Compared with descriptions (minus controls) that resolved unusual views, humorous descriptions elicited 3X greater activation in later ventral and classical reward pathways as well as the temporal poles and the orbitofrontal cortex (OFC). Increased activations in the more anterior temporal areas may reflect the activity linking remote concepts typical of the humorous interpretations. Dopaminergic projections to OFC are activated only by unexpected rewards, so the unexpected linking of the concepts in a punchline may have elicited the pleasurable response. Activation in many of these regions was also positively correlated with the funniness ratings of the stimuli provided by the subjects in the scanner. This pattern of activations to unexpected linking of remote concepts may thus be the neural correlate of the experience of visual pleasure and humor, and, with less associative activity, the more modest joy of achieving an interpretation of a single visual concept.

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Perceptual learning: Neural mechanisms

Monday, May 13, 8:30 am - 12:30 pm

Poster Session, Vista Ballroom

43.541 **Motion perceptual learning in noise improves neural sensitivity in human MT+ and IPS**

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Practice substantially improves motion direction discrimination. However, the neural mechanism of motion perceptual learning in visual noise is little understood. We studied this mechanism with functional magnetic resonance imaging (fMRI) before and after training. During training, subjects practiced six daily sessions (6,000 trials total) to discriminate motion directions of two successive random-dot kinematograms at 35% coherence, with the method of constant accuracy at 75% correct. Each subject was trained along one of the following eight directions that started from 22.5° and with an increment of 45°. Before, immediately after and two weeks after training, subjects' motion direction discrimination thresholds were measured along the directions that were 0°, 30°, 60°, and 90° away from the trained direction. Blood-oxygenation-level-dependent (BOLD) signals were also measured in a 3T GE magnet while subjects performed the same motion discrimination task along these motion directions at 75% correct. Behaviorally, practice gave rise to 48% improvement along the trained direction immediately after training and 45% improvement two weeks later, which transferred little to the untrained directions. BOLD signals were analyzed in V1, V2, V3, V3a, V5/MT+, and intra-parietal sulci (IPS), all of which were sensitive to visual motion. Compared to stimuli along the untrained directions, no significant amplitude change of BOLD signal responding to stimuli along the trained direction was found in the above ROIs. Using multi-voxel pattern analysis method, we discovered a persistent improvement of decoding accuracy in V5/MT+ and IPS for the trained direction, which lasted up to two weeks. These findings suggests that, after practice, the trained motion signal in noise could be represented and read out more accurately in the visual cortex and in the higher-level cortex respectively.

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43.542 **ERP C1 changes associated with transfer of perceptual learning at an untrained retinal location**

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The brain site of perceptual learning has been constantly debated. Recent evidence showing complete learning transfer to an untrained retinal location or orthogonal orientation suggests that perceptual learning occurs in high-level brain areas (Xiao et al., 2008; Zhang et al., 2010). Contradictorily, ERP C1 changes after learning are used as evidence for V1 plasticity because of C1's early onset (Pourtois et al., 2008; Bao et al., 2010). However, C1 can be top-down modulated (Rauss et al., 2011), which is especially likely after an observer practices/learns the same stimuli/task for several sessions. Here we measured C1 changes associated with learning transfer at a completely untrained location, with the assumption that any C1 changes observed here would indicate top-down modulation, rather than V1 plasticity. Twelve subjects were trained to discriminate grating orientation (ref_ori=36°) for five days. Two locations at 5-deg eccentricity in diagonal quadrants where obvious C1 components were evoked were used as training and transfer locations, respectively. EEGs responding to suprathreshold orientation judgment (36° or 36°±15°) were acquired pre- and post-training in separate sessions. Training improved orientation thresh-

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olds significantly (46.3%, p<0.001). Performance at the untrained location (using pretest threshold at the trained location as baseline) was also significantly improved, although by a less amount (28.3%, p<0.001). Importantly, ERP C1 increased significantly after training at not only the trained location (p=0.009), but also the untrained location (p=0.001)! These results support our hypothesis that ERP C1 is top-down modulated in perceptual learning, and that C1 changes do not necessarily indicate V1 plasticity. Bao et al. (2010) and Pourtois et al. (2008) also show no significant C1 changes if learning does not transfer to the untrained location. These associations between C1 changes and learning-induced performance improvement together suggest that C1 is likely top-down modulated by high-level perceptual learning.

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43.543 **Reconsolidation in visual perceptual learning** Ji Won Bang[1](Ji_Won_Bang@brown.edu), Sumire Sato[1], Takeo Watanabe[1], Yuka Sasaki[1]; [1]Brown University

Visual perceptual learning (VPL) is defined as long-term improvement in a visual task after visual experiences. After training is over, VPL is strengthened, or consolidated, by sleep so that VPL is not interfered with by training on a new task. In some other types of learning and memory, even after they are consolidated, they are rendered transiently malleable shortly after they are reactivated. In that case, the reactivated learning and memory becomes once again fragile to interference by training on a new task unless they are reconsolidated. Does such a reactivation effect also occur in VPL? To address this question, we used a texture discrimination task (TDT), since interference occurs between two trainings of TDTs with different background orientations with a short interval. The complete experiment consisted of 3 consecutive days. A different group of subjects participated in one of Short- and Long-interval conditions. On the first day, subjects in both conditions were trained on a TDT with one background orientation. On the following day, a brief re-test of a TDT with the trained background orientation was followed by a new training of a TDT with a new background orientation with immediate interval in the Short-interval condition and with a 6-hour interval in the Long-interval condition. On the third day, a brief re-test was conducted for the previously trained 2 TDTs with the 2 different background orientations. The results showed that the firstly learned TDT was deteriorated on the third day for the Short-interval condition, but improved for the Long-interval condition. These results indicate that a brief rehearsal of already consolidated VPL makes it vulnerable to interference, and that further reconsolidation of VPL is necessary after its reactivation to avoid it from being interfered with by a new training.

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43.544 **Using Melatonin to Study the Role of Sleep Architecture in Visual Perceptual Learning.** Joseph Arizpe[1,2](arizpej@mail.nih.gov), Madhumita Shrotri[2], Chris Baker[1], Vincent Walsh[2]; [1]Unit on Learning and Plasticity, Laboratory of Brain and Cognition, National Institute of Mental Health, National Institutes of Health, Bethesda, MD, [2]Visual Cognition Group, Institute of Cognitive Neuroscience, University College London, London, United Kingdom

Slow Wave Sleep (SWS) has been associated with consolidation of declarative memories and visual perceptual learning. This has been inferred from improved performance across an early versus late night sleep interval as the early night has a relatively high proportion of SWS. The direct relationship with SWS is unclear though as homeostatic sleep pressure, circadian phase, sleep inertia, and other physiology also differ between early and late night, and are known to affect cognition. We investigated whether these confounds could be overcome with administration of the circadian hormone melatonin, as it is know to reduce SWS and cause other physiology similar to late night sleep. Further, melatonin has a short one-hour half-life and no "hangover" effects. Thus, melatonin administration affords modulation of sleep EEG architecture at will, while also ensuring participants learn and test under the same circadian, homeostatic, cognitive, and physiological states across electrophysiological conditions. In a visual perceptual learning paradigm, we manipulated the amount of SWS during a 90-minute afternoon nap by administering 3 mg of melatonin or placebo 45 minutes before each nap. We compared the within-subject effects of melatonin versus placebo on consolidation of a classic perceptual learning task (line orientation discrimination) and on sleep EEG. As hypothesized, melatonin reduced the delta (0-4 Hz) EEG power during the nap and reduced performance improvement on the perceptual learning task. In contrast, melatonin increased performance improvement on a control task (letter discrimination) indicating that the detrimental effect of melatonin on the perceptual task is not due to a reduction in vigilance, but rather to perceptual discrimination ability per se. Our findings confirm that an afternoon nap is sufficient to consolidate perceptual learning and that SWS is directly involved in consolidation.

43.545 **Does perceptual learning require consciousness or attention?** Julia Meuwese[1](j.d.i.meuwese@uva.nl), Steven Scholte[1], Victor Lamme[1]; [1]Cognitive Neuroscience Group, Department of Psychology, University of Amsterdam, The Netherlands

Consciousness and attention have long been considered identical or overlapping processes, but recently it has been proposed that the two are in fact very different, and rely on separate neural mechanisms. This opens up a whole new set of questions in the field of perceptual learning. It is known that perceptual learning can occur 'implicitly', but thus far, little care has been given to whether the implicit nature of learning was due to a lack of attention of a lack of consciousness. We thus ask this simple question: does perceptual learning require consciousness or attention? In this fMRI experiment we presented textured figure-ground stimuli, and manipulated reportability either by masking (which only interferes with consciousness) or with an inattention paradigm (which only interferes with attention). 24 hours later learning was assessed neurally and behaviorally, via differences in figure-ground BOLD signal and via a detection task. Neural learning effects are found for stimuli presented in the inattention paradigm, and not for masked stimuli. Interestingly, the neural learning effect (for the attentional blindness group) only becomes apparent when performance feedback is given on the task that measures learning. This suggests that the memory trace that is formed during inattention is latent until accessed. Such latent learning without attention has not been shown before. Moreover, these results show that learning requires consciousness, and not attention, which further strengthens the idea that consciousness is separate from attention.

43.546 **The role of awareness on visual perceptual learning of inhibition : a fMRI study.** Yuko Yotsumoto[1](cyuko@mail.ecc.u-tokyo.ac.jp); [1]Department of Life Sciences, The University of Tokyo

Visual Perceptual Learning (VPL) is defined as a performance enhancement induced by repetitive exposure to visual tasks and/or stimuli, and has been observed both on task-relevant and on task-irrelevant stimuli. While many VPL studies were conducted in a context of increased sensitivity to the target stimulus, inhibition of the task-irrelevant noise is also its important aspect. Reduced neural responses to the irrelevant stimuli have been reported in some studies, but the role of awareness on such inhibitory VPL is still unclear. In this study, the role of awareness on the inhibitory VPL was examined using coherent random dot motion. Thirty-four subjects were divided into two groups: Supra group and Sub group. For both groups, a target direction was presented with a to-be-ignored direction. Subjects in Supra group were instructed to ignore the to-be-ignored motion direction while detecting the target motion direction. Subjects in Sub group were instructed to detect the target motion direction without knowing there was to-be-ignored motion direction hidden in the moving stimuli. All subjects underwent five behavioral training sessions. Two fMRI sessions were conducted before and after the training sessions, and BOLD signals were measured while subjects observed each motion direction. Two groups differed in sensitivity changes of the to-be-ignored motion direction. Sub group showed significant threshold decrease both in the target and to-be-ignored directions, while Supra group did not show significant sensitivity changes in either direction. Changes in BOLD signals were consistent with the behavioral changes. In Sub group, BOLD signals in MT+ for both target and to-be-ignored directions increased after the learning, while BOLD signals in Supra group tended to decrease after the learning. The results suggest two important features of VLP and awareness. First, awareness is necessary for inhibitory learning. Second spatially overlapped inhibitory attention might suppress VPL in signal detection.

Acknowledgement: KAKENHI-23680028, 24330208, SCOPE-112103017

43.547 **Unconscious Reward Signal Promotes Motion Perceptual Learning** Xin Xue[1](xxue@pku.edu.cn), Sheng Li[1,2]; [1]Department of Psychology, Peking University,China, [2]Key Laboratory of Machine Perception (Ministry of Education), Peking University,China

It is assumed that reward signal gates visual perceptual learning (Roelfsema, Ooyen and Watanabe, 2009). However, it remains unclear whether such gating effect can be dissociated from attentional biases. Here we investigate this issue using unconsciously perceived monetary reward during motion perceptual learning. Seventeen subjects were trained to detect coherent motion of two directions for four daily sessions. During the training, one motion direction was paired with subliminally presented high-value reward, and the other direction was paired with subliminally presented

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low-value reward. In order to maintain subjects' attention on the subliminal reward feedback, catch trials in which reward feedback was replaced by visible checkerboard were inserted in the training. Subjects were instructed to detect these occasionally presented checkerboards. Before and after the training, we measured subjects' psychometric functions on two trained motion directions. Changes in detection threshold and slope at 75% accuracy level were calculated. We also measured subjects' awareness level of reward value and recognition level of reward-direction contingencies. The results showed that decrease of the detection threshold was significantly larger for the motion direction paired with high reward value compared to the direction paired with low reward value ($p<0.05$). The increase of the slope of the psychometric function was also significantly larger for the high reward direction compared to the low reward direction ($p<0.05$). The reward effect on perceptual learning could not be explained by attentional biases. Awareness tests before and after the training indicated that subjects were unconscious of the reward value and the reward-direction contingencies. Our findings suggest that reward signal promotes motion perceptual learning, even if the reward feedback was unconsciously perceived.

Acknowledgement: National Natural Science Foundation of China (31271081, 31230029, 31070896),National High Technology Research and Development Program of China (863 Program) (2012AA011602).

43.548 **The role of rSMG in volitional eye movements**

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We investigated the role played by the human supra-marginal gyrus (SMG) when observers learnt a task involving predictable sequences of saccadic eye movements. Typically, such sequence learning occurs very quickly (after one or two trials), and results in predictive eye movements that have shorter latencies compared to saccades made when the position is not known. Importantly, we demonstrate that when SMG function in the right cerebral hemisphere is disrupted using MRI-guided Transcranial Magnetic Stimulation (TMS) (see Figure 1, sup material), the ability to make short latency anticipatory saccades is significantly impaired. This is in contrast to random sequences (where the pattern of eye movements cannot be learned), and delivery of TMS to the right SMG had no effect (see figure 2, sup material). These results indicate that neural activity within the right SMG is essential for the processing and release of visual information necessary for making early predictive motor responses.

43.549 **No Stress With Perceptual Learning**

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Stress modulates declarative learning. Only a few studies have examined the influence of stress on non-declarative learning. Here, we examined the effects of a stressor, that significantly affects declarative learning, on a non-declarative perceptual learning task. On day one, participants performed a texture discrimination task. Following learning, participants submersed their forearm and hand in either ice-water or lukewarm water. The ice-water condition has previously been shown to improve declarative learning (Cahill, Gorski & Le, 2003). On day two, participants returned for a subsequent session with the same task. Only participants in the ice-water group had significantly elevated cortisol levels. However, contrary to similar declarative learning studies, we found no effect of increased stress on perceptual learning. These results suggest a functional segregation in the effects of stress hormones on cortical plasticity related to low-level perceptual learning and high-level declarative learning.

Acknowledgement: Sinergia project of the SNF

43.550 **Functional and structural correlates of face view perceptual learning in human brain**

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Object recognition and discrimination can be significantly improved by perceptual learning. However, the neural mechanism of object perceptual learning remains illusive. In this study, we searched for the functional and structural correlates of face view discrimination learning in human brain. Subjects were trained to discriminate face views around an in-depth face orientation of 30°over eight daily sessions, which resulted in a significant improvement in sensitivity to the face view orientation. This improved sensitivity was highly specific to the trained orientation and persisted up to one month. Before, immediately after and one-month after training, subjects underwent MRI scans to obtain functional and structural brain images. We first performed univariate amplitude analysis and multivariate pattern analysis of BOLD signals responding to the trained and untrained face views in six face selective cortical areas (OFA, STS and FFA in both hemispheres). We found that, relative to the untrained views, the mean amplitude of BOLD signal in the left and right FFA increased for the trained view immediately after training. But the increase was short-lived and it disappeared one month later. On the other hand, training improved the stability of the spatial activity pattern for the trained view in the left FFA. The improvement persisted even one month later and was correlated with the behavioral improvement. Then, we performed an ROI analysis of the face selective areas and a whole cortical surface analysis to measure cortical thickness before and after training. Although little cortical thickness change was detected after training, we found that the cortical thickness of the left FFA before training was inversely correlated with the behavioral improvement. That is, the thinner the cortex in the left FFA, the greater the learning effect. Taken together, these findings provide converging evidence that the left FFA plays a pivotal role in adaptive face processing.

Acknowledgement: This work was supported by the National Natural Science Foundation of China (Project 91024032, 30925014 and 90920012) and the Ministry of Science and Technology of China (2011CBA00405 and 2010CB833903).

43.551 **Reading Speed in Peripheral Vision Improves with Practice: Investigation of the Involved Cortical Sites**

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Reading speed in peripheral vision improves with practice, but the cortical site of this improvement is not understood. Using psychophysics and fMRI, we investigated the potential training-related functional changes in retinotopic and non-retinotopic cortical areas. Ten young normally sighted subjects were trained (1hour/day over 4days) to read sentences displayed in the lower visual field (10º eccentricity) using the Rapid Serial Visual Presentation (RSVP) paradigm. Pre- and post-training psychophysical tests included RSVP reading speed, visual span and orientation discrimination (Gabor patch) measurements in both the trained (lower) and untrained (upper) visual fields. Functional MRI measurements (BOLD) were recorded before and after training for eccentric RSVP reading (at four presentation rates) and grating orientation discrimination. The fMRI measurements used a rapid event-related design, with analysis focusing on three cortical regions: the primary visual cortex, Broca's area and the visual word form area (VWFA). Training resulted in a significant gain (60% ±25%) in RSVP reading speed in the trained visual field, and partial transfer of this improvement to the untrained upper visual field. The fMRI results showed that the activity level in VWFA was dependent on the presentation rate and in turn was positively correlated with the percentage of words accurately recognized. More specifically, before training, BOLD activity in VWFA was significantly weaker ($p<0.01$) for the fastest (hardest) reading condition than for the slowest (easiest) one, but this difference was significantly reduced after training. A weaker but similar trend was observed in retinotopic cortex as well. Our results show that VWFA response during reading in peripheral vision is affected by a training protocol that enhances reading speed. The more uniform VWFA responses at the four RSVP rates following training may be associated with higher word recognition accuracy for the faster rates which in turn yield shallower behavioral psychometric functions.

Acknowledgement: Supported by NIH grant EY002934

43.552 **Training-induced recovery of low-level vision followed by high-level perceptual improvements in an adult with developmental object and face agnosia**

Sharon Gilaie-Dotan[1](shagido@gmail.com), Maria Lev[2], Dana Gotthilf-Nezri[2], Oren Yehezkel[2], Anat Perry[3,4], Shlomo Bentin[3,5], Yoram Bonneh[6], Uri Polat[2]; [1]Institute of Cognitive Neuroscience, UCL, London, UK, [2]Faculty of Medicine, Goldschleger Eye Research Institute, Tel Aviv University, Tel Hashomer, Israel, [3]Department of Psychology, Hebrew University of Jerusalem, Jerusalem, Israel, [4]Department of Psychology, University of Haifa, Haifa, Israel, [5]Center for Neural Computation, Hebrew University of Jerusalem, Jerusalem, Israel, [6]Department of Human Biology, University of Haifa, Haifa, Israel

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Long-term deprivation of normal visual inputs can cause perceptual impairments at various levels of visual function, from basic visual acuity deficits, to high-level face and object agnosia. Yet it is unclear whether training during adulthood, at a post-developmental stage of the adult visual system can overcome such developmental impairments. Here, we visually trained LG, a 20-year-old individual with a developmental object and face agnosia. Prior to training, LG's basic visual functions such as visual acuity, crowding effects, and contour integration were at the level of a 5-6 year old. Intensive visual training, based on lateral interactions, was applied for a period of nine months. LG's directly trained but also untrained visual functions such as visual acuity, crowding, and contour integration improved significantly and reached near-age-level performance, with long-term (over 2 years) persistence. Moreover, the training facilitated additional binocular functions, and some improvement was observed in LG's higher order visual functions such as object recognition and part integration. LG's face perception skills have not improved thus far. These results suggest that corrective training at a post-developmental stage, even in the adult visual system, can prove effective, and its enduring effects are the basis for a revival of a developmental cascade that can lead to reduced perceptual impairments.

Acknowledgement: Grants from National Institute for Psychobiology in Israel, funded by the Charles E. Smith Family and the Israel Science Foundation (ISF, grant number 188/10)

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Tuesday Morning Talks

Eye Movements: Targeting

Tuesday, May 14, 8:15 - 9:45 am
Talk Session, Royal Ballroom 1-3
Moderator: Constantin Rothkopf

51.11, *8:15 am*

A modular soft barrier model combines uncertainty and reward to predict human eye movements in a two-task driving environment Leif Johnson[1](leif@cs.utexas.edu), Brian Sullivan[2,3], Mary Hayhoe[2], Dana Ballard[1]; [1]Computer Science Department, UT Austin, [2]Center for Perceptual Systems, UT Austin, [3]Smith-Kettlewell Eye Institute

We present a control model of visual attention in driving that uses explicit representations of task goals, reward and task uncertainty to predict arbitration of eye movements among multiple tasks in a naturalistic environment, modeled on human data from Sullivan et al. (in press). Their experiment manipulated implicit reward and uncertainty in a two-task virtual driving environment while measuring gaze behavior and task accuracy. Subjects drove through a virtual city and were explicitly instructed to drive at an exact speed while simultaneously follow a leader car. Implicit relative reward was manipulated by additional instructions that emphasized the importance of either the exact-speed or the following-the-leader task. Uncertainty was manipulated by adding perturbations to the car's speed, and was intended primarily to disrupt the exact-speed task. Indeed, when maintaining an exact speed was emphasized, adding uncertainty increased fixations on the speedometer. However, when following another car was emphasized, adding speed uncertainty had no effect on speedometer fixations. This interaction between reward and uncertainty suggests that subjects allocate gaze to uncertain task-relevant objects only when that task is associated with relatively high reward. We translated the high-level modular design of Sprague et al. (2007) into the dynamic driving world by allocating PID controllers to each driving task and modeling the propagation of error as a random walk. The model allocates eye movements to task-relevant objects using a "soft" barrier that defines a Boltzmann distribution over reward-weighted task uncertainties. This model closely matches the distribution of human gaze over time in the driving data, achieving a mean KL divergence from human data that is significantly lower than that from round-robin and constant-probability baselines. Additionally, the model is able to capture elements of task switching dynamics exhibited by human drivers.

51.12, *8:30 am*

Temporal Oculomotor Inhibition of Return and Spatial Facilitation of Return in a Visual Encoding Task Steven G. Luke[1,2](lukesg@mailbox.sc.edu), Joseph Schmidt[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

Oculomotor inhibition of return (O-IOR) is an increase in saccade latency when returning to a recently fixated location relative to other locations. It has been proposed that this temporal O-IOR has spatial consequences, facilitating foraging by inhibiting return to previously attended regions (Klein & MacInnes, 1998). Models of visual attention incorporate this spatial IOR effect to drive attention to new locations. However, the foraging facilitator hypothesis has been a matter of debate recently in the scene literature, with several studies observing increased rather than decreased return probability (Hooge et al., 2005; Smith & Henderson, 2009, 2011a,b). To test whether spatial O-IOR occurs and can facilitate foraging, we monitored participants' eye movements while they viewed arrays of objects or words. Arrays were chosen over scenes because arrays offer the advantage that fixation locations can be unambiguously assigned to specific objects. Temporal O-IOR was observed for both objects and words, but there was no evidence for spatial O-IOR. Instead, we observed spatial facilitation of return; participants were more likely than chance to refixate just-visited locations. Further, the likelihood of making a return saccade to an object or word was contingent on time spent previously on that object or word, suggesting that return saccades are triggered when further visual information is needed. The results also revealed strong evidence for saccadic momentum, an oculomotor bias to repeat the most recently executed saccade program. Such repetitions were the most frequently-occurring saccades in our data. Taken together, these results suggest that inhibition of return is not a foraging facilitator. We suggest that models of visual attention could incorporate saccadic momentum as a foraging facilitator instead of O-IOR. We further suggest that such models should incorporate a mechanism that triggers return saccades when more information is needed from a location.

Acknowledgement: National Science Foundation (BCS-1151358) awarded to John M. Henderson.

51.13, *8:45 am*

Infants in Control - Rapid Learning of Action Outcomes by 6 and 8-Month-Olds in a Gaze-Contingent Paradigm Quan Wang[1], Jantina Bolhuis[2], Constantin Rothkopf[1], Thorsten Kolling[2], Monika Knopf[2], Jochen Triesch[1]; [1]Frankfurt Institute for Advanced Studies, Frankfurt, Germany, [2]Department of Psychology, Goethe-University Frankfurt, Frankfurt, Germany

Infants' poor motor abilities limit their interactions with the environment and render studying infant cognition notoriously difficult. Exceptions are eye movements, which reach high accuracy early, but generally do not allow manipulation of the physical environment. In this study, we employ a gaze-contingent paradigm using real-time eye tracking to put 6- and 8-month-old infants in direct control of their visual surroundings. We use this paradigm to study the fundamental problem of discovery of agency by allowing the infant to change a central image on a screen by looking at a peripheral red disc, which functions as a switch. We demonstrate that infants quickly learn to perform eye movements to trigger the appearance of new stimuli and that they anticipate the consequences of their actions in as few as 3 trials. Interestingly, the infants perform better than a majority of adult subjects tested under identical conditions. Our findings show that infants can rapidly discover new ways of controlling their environment. We suggest that gaze-contingent paradigms offer effective new ways for studying many aspects of infant learning and cognition in an interactive fashion and provide new opportunities for behavioral training and treatment in infants.

Acknowledgement: The authors would like to thank the BMBF Project

51.14, *9:00 am*

If you cannot see it, you look at it: Visual conspicuity in real-world scenes is correlated with fixations Lavanya Sharan[1,2](sharan@alum.mit.edu), Ruth Rosenholtz[1,2]; [1]Department of Brain & Cognitive Sciences, Massachusetts Institute of Technology, [2]Computer Science and Artificial Intelligence Lab, Massachusetts Institute of Technology

Where we look in a real-world scene depends on a number of factors, including stimulus properties (e.g., local contrast), task, and constraints of human visual processing (e.g., acuity loss in peripheral vision). Previous work has examined the role of bottom-up saliency (Itti & Koch, 2000) and task-driven eye-movement planning (Najemnik & Geisler, 2005; Renninger et al., 2007) in determining eye movements. Purely bottom-up saliency cannot account for eye movements in real-world scenes; rather, top-down influences have to be considered (Oliva et al., 2003; Henderson et al., 2007; Tatler et al., 2011). Furthermore, humans seem to use eye-movement strategies that account for the limitations of peripheral vision and maximize task-specific information gain (Peterson & Eckstein, 2012). In this work, we test an alternative way of conceptualizing eye movements in terms of visual conspicuity (Engel, 1971). The conspicuity of a target measures the maximum eccentricity at which the target viewed peripherally looks the same as an identical target presented foveally. This measure includes both bottom-up and top-down aspects of visual recognition and is constrained by the limitations of peripheral vision. Target conspicuity is correlated with the probability of finding a target in simple displays (Engel, 1977) and with search times in restricted real-world settings (Toet et al., 1998). We extend these findings to a "free-viewing" memory task and unrestricted real-world scenes. We use images from the MIT Eye Tracking Dataset (Judd et al., 2009) and show that the regions that elicit fixations have lower conspicuity (i.e., are harder to resolve in the periphery) than the regions that do not elicit fixations. In addition, conspicuity succeeds where a state-of-the-art saliency model (Judd et al., 2009) does not; regions incorrectly predicted to be salient have higher conspicuity values than correctly predicted regions.

Acknowledgement: NIH

51.15, *9:15 am*

Task-dependent priming of fixation selection for recognition of natural scenes

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Eye fixations allow the viewer to visually perceive with high spatial acuity. Here, we tested the role of fixations for scene memory. If fixations drive scene memory, a viewer should repeat a previous fixation pattern when recognizing a scene (Noton & Stark, 1971; Underwood, Foulsham, & Humphrey, 2009). However, salience of low-level features can also account for similarities between two successive fixation patterns within the same images, by attracting the eyes in a stimulus-driven, task-independent manner (Kaspar & König, 2011). Therefore, we tested whether the viewer's aim to recognize a scene fosters fixations that repeat from learning to recognition. In Experiment 1 we varied the viewing task (recognition vs. free-viewing) between viewers, and compared the extent of repeated fixation patterns between the groups. By showing the same images in both tasks, salience was held constant. We found that the similarity of successive fixation patterns was significantly higher under recognition than under free viewing conditions. Furthermore, viewers fixated significantly more on repeated scene content during recognition but not during free viewing. In Experiment 2 we applied a gaze-contingent presentation of images to test whether participants remembered visual input that they fixated during learning better than salient but non-fixated visual input. To that end, we presented viewers with much smaller cutouts (at screen center) from the previously learned full screen scenes. We found that cutouts featuring previously fixated scene content were recognized better and faster than cutouts featuring non-fixated but highly salient scene content. We conclude that fixations serve visual memory for natural scenes over and above a stimulus-driven influence of visual salience, and discuss how our results relate to memory-based effects, such as priming, reported in the visual search literature.

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51.16, *9:30 am*

Reconsideration of the functionality of human Frontal Eye Fields.

Christopher Tyler[1](cwt@ski.org), Lora Likova[1], Spero Nicholas[1]; [1]Smith-Kettlewell Eye Research Institute

Introduction. The Frontal Eye Fields (FEF) are conventionally designated as a region of frontal cortex activated in conjunction with eye movement tasks. However, most studies of their function employ a wide array of working memory (WM), spatial attention, visual search tasks and cognitive tasks such as mathematical calculation. Here we ask what form of neural coding could underlie the processing of such a wide variety of mental processes, and whether they can be meaningfully associated with an oculomotor function. Methods. Functional MRI of human observers at 3T in a whole-brain paradigm morphed to the MNI brain coordinates was used to contrast a) the activation in a simple, attentionally non-demanding, repetitive left-right saccade task involving only two eye muscles per eye with b) activation in an advanced calculation (working memory) task of adding, subtracting, multiplying or dividing three-digit numbers with controlled fixation. Results. 1. Both task activations overlapped only in the dorsal FEF. 2. Surprisingly, activation in the ventral FEF, also a well-known saccadic area, was virtually eliminated in the simple saccade task. 3. The calculation WM activated the full extent of the premotor cortex, commonly activated in WM tasks. 4. The saccadic task bilaterally activated a small well-focused region of the primary motor cortex (M1) centered within the face region. Conclusion. Although part of premotor cortex is commonly designated as the dorsal 'FEF' for eye movement control, its ubiquitous activation in non-oculomotor WM and other cognitive tasks implies a much broader role beyond oculomotor functions. The ventral 'FEF' activation we found in the calculation task partially overlaps with Broca's area, and may support a subvocal component of the WM operation. Finally, the local patch of M1 activation is suggested as the specific eye muscle control region (from the ~650 muscles controlled by the 'homunculus' of the full M1 strip).

Acknowledgement: CDMRP 102524

Visual memory: Mechanisms

Tuesday, May 14, 8:15 - 9:45 am

Talk Session, Royal Ballroom 4-5

Moderator: Nicholas B. Turk-Browne

51.21, *8:15 am*

At the interface of visual perception and long-term memory: Object knowledge and the medial temporal lobe

Michael F. Bonner[1](michafra@mail.med.upenn.edu), Amy R. Price[1], Jonathan E. Peelle[2], Murray Grossman[1]; [1]Department of Neurology, University of Pennsylvania, [2]Department of Otolaryngology, Washington University

Along the ventral visual pathway, neurons are increasingly selective for complex features and invariant to low-level details. This hierarchy culminates in the medial temporal lobe (MTL), where neurons exhibit highly selective and invariant responses to objects, responding even to the spoken and written names of objects. One interpretation of these findings is that MTL neurons encode a stable representation of visual concepts, providing a link between ongoing visual perception and long-term object knowledge. We tested this MTL hypothesis in three experiments that investigate the neural basis of visual concepts. In an fMRI experiment, healthy adults (N=16) performed a semantic matching task on word triads that varied on their visual feature associations. fMRI analysis showed that visual features parametrically modulated activity in the MTL and fusiform gyrus ($p<.05$, whole-brain corrected), such that highly visual words resulted in increased activation. Furthermore, subjects had a processing advantage for highly visual words (faster reaction times), and structural MRI analysis revealed that individual differences in the degree of this processing advantage correlated with gray matter density of the hippocampus (rho=.7, $p=.002$). We next administered this task in patients with semantic dementia (N=8), a neurodegenerative condition affecting the anterior temporal lobes. We compared performance on two linguistically matched subgroups of triads: visual and abstract (mean visual association ratings=5.5 and 0.6, respectively). Controls made few errors but were worse on abstract triads ($p<.05$). Patients were impaired overall, but varied considerably on their performance for visual relative to abstract triads. A whole-brain regression analysis revealed a strong relationship between decreased gray matter density in the MTL and impaired knowledge of visual concepts relative to abstract concepts ($p<.05$, whole-brain corrected). It appears that MTL structures at the apex of the ventral visual stream may underlie the interaction of visual perception and the long-term representation of object concepts.

Acknowledgement: National Institutes of Health AG015116 and AG017586

51.22, *8:30 am*

Decoding invariant representations in visual working memory

Thomas Christophel[1,2](tbchristophel@gmail.com), Christian Endisch[1,2], John-Dylan Haynes[1,2,3,4,5]; [1]Bernstein Center for Computational Neuroscience, Charité Universitätsmedizin, Berlin, Germany, [2]Berlin Center for Advanced Neuroimaging, Charité Universitätsmedizin, Berlin, Germany, [3]Berlin School of Mind and Brain, Humboldt Universität, Berlin, Germany, [4]Cluster of Excellence NeuroCure, Charité Universitätsmedizin, Berlin, Germany, [5]Department of Psychology, Humboldt Universität, Berlin, Germany

Visual shape recognition can exhibit considerable invariance across changes in visual appearance and viewing position (Cichy, Chen, & Haynes, 2011; Edelman, 1997; Grill-Spector, Kourtzi, & Kanwisher, 2001). This raises the question whether also the retention of shape information in visual working memory (Baddeley & Hitch, 1974) exhibits such invariance. Here, we specifically investigated whether objects memorized across brief delays are encoded using a rotation-invariant code. While positioned in an MRI scanner, 22 healthy subjects memorized simple shape stimuli. To prevent subjects from using a semantic code, we chose abstract decagons as stimuli. These are randomly generated ten-sided shapes. In each trial, subjects had to memorize one shape indicated by a retro-cue method controlling for perceptional confounds (see Harrison & Tong, 2009). After a delay of 10 seconds, subjects had to identify which of two test decagons had a more similar shape (see Christophel, Hebart, & Haynes, 2012). Importantly, sample and test decagons were shown in random 2D-rotations to encourage the use of rotation-invariant representations. We used fMRI in combination with time-resolved multivariate searchlight decoding to identify areas that maintained the memorized object during the delay period using a rotation-invariant code (Cichy et al., 2011; Haynes & Rees, 2006; Kriegeskorte, Goebel, & Bandettini, 2006). Testing for classifier generalization between different rotational views of the same shape, we identified three regions that showed significant ($p(FWE) <0.05$) memory-specific information

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bilaterally: Lateral occipito-temporal cortex, posterior parietal cortex and the human frontal eye fields (see Petit, Clark, Ingeholm, & Haxby, 1997). These results demonstrate that invariant shape-coding in working memory is prevalent in perception-driven areas across the brain (see Postle, 2006). Importantly, our findings demonstrate that invariant visual memory representations do not require higher-order dorso-lateral prefrontal areas.

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51.23, *8:45 am*

Memory for Size vs. Memory for Relative Size

Pamela Glosson[1](glosson2@illinois.edu), John Hummel[1]; [1]University of Illinois at Urbana-Champaign

A great deal of research in vision relies on the assumption that memory for absolute size is better than memory for relative size. View based models (e.g., Poggio & Edelman, 1990) recognize objects using absolute size. These models suggest we hold an exact size in memory for later object recognition, and do not consider relative sizes explicitly. Structural description models, on the other hand, emphasize categorical—not metric—size relations (e.g., Hummel & Biederman, 1992). Our study investigates memory for absolute size versus relative size. If we should find that memory for relative size is more precise than memory for absolute size, then this result would be inconsistent with both classes of models. In our study, subjects judge size difference between two shapes and relative size difference between two pairs of shapes. We vary the ratio of size differences, the exposure duration of the study object or pair, and the delay (ISI) between study and test. We found that subjects' memory was more precise for relative size trials than for absolute size trials at all exposure durations, even the shortest. We also found that memory for relative size persists over a longer delay than memory for absolute size. Our findings suggest that memory for relative size is more accurate and more robust than memory for absolute size. Given the fact that absolute size on retina changes (when objects are at different distances), but relative size stays the same (over changes in distances), relative size carries more information.

51.24, *9:00 am*

Image Memorability in the Eye of the Beholder: Tracking the Decay of Visual Scene Representations

Melissa Vo[1](mlvo@search.bwh.harvard.edu), Zoya Gavrilov[2], Aude Oliva[2]; [1]Harvard Medical School, BWH, [2]CSAIL, MIT

Some images you have seen stick to your mind for days, weeks, or even years, while others are fleeting and seem to vanish quickly from memory. Recent work has shown that the memorability of an image is consistent across context and observer, suggesting that intrinsic image features determine how well an image will be later remembered (Isola et al., 2011). In this study, we tested whether differences in image memorability are 1) stable over time, 2) affected by image rotation (impeding semantic access), and 3) whether the retrieval of images with different memorability scores affords differential degrees of cognitive load mirrored by graded pupillary responses. We tracked participants' pupillary responses while they viewed a sequence of >1200 images for 2 sec each with the instruction to press a key whenever they noticed that an image had repeated. 240 target images from 3 non-overlapping memorability classes (low medium, high) were repeated at 4 different lags (8, 16, 64, and 256 intervening images). Overall, performance decreased log-linearly with time. Differences in memorability were already clearly visible at the shortest lag (~8 intervening images or 20 sec) and became more pronounced as time passed on (~256 intervening images or 11 min). Further, images shown upside down resulted in performance decrements, but interestingly, memorability rank orders remained unaffected with little performance decrements for high memorable compared to low memorable images. This suggests that image semantics promote successful memorization especially when an image is difficult to keep in mind. Importantly, we found that pupils dilated significantly more to correctly identified targets than correctly rejected distractors. This "pupil old/new effect" (Võ et al., 2008) increased with increasing number of lags and decreasing image memorability suggesting that during memory retrieval of scenes image inherent semantic and visual features pose differential degrees of cognitive load on an observer.

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51.25, *9:15 am*

Pruning of visual memories based on contextual prediction error

Ghootae Kim[1](ghootaek@princeton.edu), Jarrod A. Lewis-Peacock[1,2], Kenneth A. Norman[1,2], Nicholas B. Turk-Browne[1,2]; [1]Department of Psychology, Princeton University, [2]Princeton Neuroscience Institute, Princeton University

Visual experience leaves incidental traces in long-term memory. This encoding happens continuously and automatically, resulting in a potentially overwhelming number of memories. How does the brain decide whether to preserve or discard a visual memory over time? We propose a new 'contextual unreliability' principle for memory management based on visual statistical learning and prediction error: Memory for an object should be weakened if the object fails to appear in a visual context with which it has been associated. We tested this hypothesis in an fMRI study. Observers were exposed to a continuous sequence of faces and scenes while performing a cover task. Unbeknownst to them, this sequence was generated from triplets (e.g., faceA-faceB-sceneC). The first two 'context' stimuli in each triplet were later repeated, but to create contextual unreliability, a new stimulus appeared in the third position (e.g., faceA-faceB-faceD). We hypothesized that if the original third stimulus (e.g., sceneC) had been associated with the now-unreliable context, then this violation would lead to forgetting. To measure the contextual association for each third stimulus, we used multivariate pattern analysis to decode its category during the repeated context (e.g., how much scene information about C was present during faceA-faceB-faceD). We then related this 'prediction' strength to subsequent memory, and found a negative relationship: strongly (and incorrectly) predicted stimuli were recognized less well than weakly predicted stimuli and control stimuli not part of a context triplet. To verify that this category-level classifier reflected a specific prediction of the original third stimulus, we replicated all results with representational similarity analysis: Strong exemplar-level reinstatement of the third stimulus in the repeated context produced greater forgetting. These findings provide insights into how memory systems incorporate contextual information to manage preexisting representations. Moreover, they reveal dynamic and implicit interactions between memory mechanisms and the visual system during perception.

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51.26, *9:30 am*

The content of visual working memory is prioritized for conscious access.

Surya Gayet[1](S.Gayet@uu.nl), Chris Paffen[1], Stefan Van der Stigchel[1]; [1]Department of Experimental Psychology, Utrecht University, Helmholtz Institute

In a series of experiments we tested whether information that matches the content of visual working memory (VWM) is prioritized by the visual system, such that this information reaches visual awareness faster than non-matching information. Trials in our experiments consisted of three phases: first, a colored patch (i.e. the cue) was shown, which participants were instructed to either remember (memory condition) or not (passive viewing). Next, a target was erased from awareness by interocular suppression: a target, either matching the color of the cue or not, gradually increased in intensity for one eye, while a high contrast dynamic pattern was presented to the other eye. Participants were instructed to press a button as soon as they detected the target. In the final phase of the color memory condition, three colored patches were presented. Participants indicated which of the targets matched the cue. The results show that targets that matched the memorized color broke through interocular suppression faster than non-matching targets. In contrast, the passive viewing condition showed no such color congruency effect. Importantly, a control experiment revealed that when the target and the dynamic pattern were presented to the same eye no difference was observed between the color memory condition and the passive viewing condition. In another experiment, we ruled out the possibility that the congruency effect was caused by deeper initial processing of the memorized cue; two color stimuli were subsequently presented, followed by a postcue indicating which of the two stimuli should be retained. The color congruency effect was still observed under these conditions. Together, these findings show that conscious access is prioritized for information matching the content of VWM. We suggest that VWM, a system that retains visual information for imminent goal-directed behavior, is recruited to funnel down the sensory input to that which requires conscious access.

Binocular Vision

Tuesday, May 14, 10:45 - 12:30 pm

Talk Session, Royal Ballroom 1-3

Moderator: Ben Backus

52.11, *10:45 am*

Binocular Vision: In the Beginning Allan Dobbins[1](adobbins@uab.edu); [1]Dept. BME, Vision Science Research Center, University of Alabama at Birmingham

Stereopsis requires the ability to align the eyes. We describe a two phase developmental theory undergirded by neurons of qualitatively different character. Recent work has found that, across multiple species, orientation maps in V1 are characterized by a remarkable property: the density of singularities per hypercolumn area is constant. By no means a feature of all orientation maps, simulations show that this is a universal property of maps that arise from dynamics that have long-range inhibition (Kaschube et al., 2010 Science, 330: 1113). We predict that long-range inhibition will also be a defining characteristic of ocular dominance maps. In our theory, segregation of the inputs to the eyes in V1 is followed by a set of randomly directed inhibitory connections between ocular dominance columns. The result of the long-range interactions are neurons excited primarily through one eye and inhibited primarily through the other. Across the population, there is sensitivity to all directions of binocular disparity, and inhibition gives rise to a broad disparity-dependent response modulation that is suitable as an error signal for aligning the eyes. For example, neurons on the horizontal meridian sensitive to vertical disparity can be combined to provide signals for torsional error correction. In addition, the asymmetric ocularity conserves eye-of-origin information and so provides a foundation for the representation of monocular regions in occlusion-based stereopsis. The characteristics described above are precisely those of a subset of the neurons termed Near and Far cells in earlier studies. Therefore, we postulate that the key aspects of the first stage of stereopsis are: (i.) eye-of-origin conservation, and (ii.) a qualitative disparity map that provides error signals for ocular alignment. Strikingly, this depends on apparently monocular neurons. Stage 2 involves correlation cells underlying fine stereopsis. Implications for squirrel monkey will be discussed.

52.12, *11:00 am*

Solving the binocular correspondence problem with ghost matches Bart Farell[1,2](bfarell@syr.edu); [1]Institute for Sensory Research, Syracuse University, [2]SUNY Eye Institute, State University of New York

Binocular vision's correspondence problem arises when veridical interocular matches are camouflaged by false ones. This fundamental issue in stereo theory can be approached in a new way by making use of the symmetrical patterns of false or 'ghost' matches found within the Keplerian array of all possible matches. This ghost-match symmetry locates true matches (which live on the axes of symmetry) and reveals the shape of the surface that gave rise to them. The symmetry is a general outcome of binocular viewing of surfaces, be they frontoparallel, slanted, or curved, and the shape of the surface is described by the parameters of a small set of transformations operating across the symmetry axis. It is hypothesized that the visual system uses ghost symmetry to find true matches and recover surface shape. To see whether this signal is used, I tested a prediction of the symmetry hypothesis: In the presence of a masking pattern, small target stimuli should yield lower disparity thresholds than large targets in a depth discrimination task. Anti-correlated noise maskers fulfill the requirements for this prediction; uncorrelated noise maskers serve as a control. Observers were briefly shown a bipartite Gabor patch. The task was to judge which half of the patch was 'nearer'. Disparity thresholds dropped as the patch was made narrower, but only in anti-correlated noise, as predicted. As the horizontal space constant of the Gaussian contrast envelope shrank from 1.5 to 0.25 degrees of visual angle, thresholds dropped 5-fold, reaching the level found for uncorrelated noise. Other experiments were also consistent with ghost symmetry's contribution to stereo depth. This distributed and multi-scale signal supports a potentially robust approach to a correspondence solution; it also suggests new ways of combining stereo and motion signals and of understanding the physiology underlying disparity processing.

52.13, *11:15 am*

Motion perception in RDK with signal and noise dots distributed across eyes Lanya Tianhao Cai[1,2](tcai@sunyopt.edu), Alexander Yuan[1,2], Benjamin Backus[1,2]; [1]Graduate Center for Vision Research, SUNY College of Optometry, [2]SUNY Eye Institute

Interocular suppression can be quantified using random-dot kinematograms (RDK) in dichoptic views, with coherently moving signal dots in one eye and randomly moving noise dots in the other. People with normal vision combine visual information into a fused image, so that signal detection is compromised by noise in either eye (Edwards, Badcock, and Nishida, Vis Res 1996; Hess, Mansouri, and Thompson, OVS 2010). However, the details of this combination are unclear. We used dichoptic stimuli in which signal and noise dots had different luminance contrasts in order to measure contrast-ratio thresholds in a 2AFC motion discrimination task. Observers had normal vision. They viewed stimuli through a stereoscope and reported the motion direction of the signal dots (up or down). A 3-down 1-up staircase controlled luminance contrasts. Signal and noise dots were independently divided between the eyes (0%, 25%, 50%, 75%, 100% to the left eye), which gave 25 dot-distribution conditions. There were three levels of global percent coherence (8%, 16%, 24%). We found that logCR threshold decreased with increasing percent coherence, and there was a small practice effect. The 25 conditions were grouped in several ways to measure characteristics of binocular combination. All observers slightly preferred binocular signal. Some observers had lower thresholds with signal and noise in different eyes, monocular noise, and monocular stimuli generally: they were able to exclude monocularly presented noise. Others preferred having signal and noise together in the same eye(s), binocular noise, and binocular stimuli generally: noise in one eye caused suppression of the other. All observers appear to have looked for signal within a binocularly combined representation, but they differed in their strategies for excluding noise. The data also revealed two regimes that observers used to do the task: reliance on global percent coherence or segregation of signal from noise by contrast grouping.

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52.14, *11:30 am*

Color and Luminance Influence, but Can Not Explain, Binocular Rivalry Onset Bias Jody Stanley[1](jodys@unimelb.edu.au), Jason Forte[1], Patrick Cavanagh[2], Olivia Carter[1]; [1]School of Psychological Sciences, University of Melbourne, [2]Laboratoire Psychologie de la Perception, Universite Paris Descartes

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 the initial 'onset' period of rivalry is not random and may be different in its neural mechanism than subsequent dominance periods. It is known that differences in luminance and contrast have a significant influence on the average dominance during sustained rivalry and that perception of luminance can vary between individuals and across the visual field. We therefore investigated whether perception of luminance contrast plays a role in onset rivalry. Rival targets were matched for brightness in each of eight locations of the near periphery for each observer. Observers then viewed the rival targets for brief presentations in each of the eight locations and reported the color that was first dominant in each location. Results show that minimizing differences in brightness and contrast yields a stronger pattern of onset dominance bias and reveals evidence of monocular dominance. Specifically, a significant advantage was observed for the temporal hemifield, with the left or right eye's image each significantly more likely to dominate when it was presented in left or right visual field locations respectively. These results suggest that both contrast and monocular dominance play a role in onset dominance, though neither can fully explain the effect. Drawing from additional current research, a brief overview of other factors contributing to dominance at the onset of rivalry will also be presented. Together, these results further clarify the distinction between perceptual dominance at onset and the dominance periods during subsequent alternations.

52.15, *11:45 am*

Multi-stable perception of structure-from-motion: differential priming selectivity distinguishes sensory memory and neural fatigue Alexander Pastukhov[1](alexander.pastukhov@ovgu.de), Jana Füllekrug[1], Jochen Braun[1]; [1]Center for Behavioral Brain Sciences, Magdeburg, Germany

Ambiguous displays often lead to spontaneous alternations of mutually exclusive perceptions (multi-stable perception). Structure-from-motion (SFM) displays induce a vivid perception of a 3D volume rotating in depth, which reverses spontaneously from time to time. When an SFM display is interrupted briefly (~0.5 s), the current perception is destabilized by neural fatigue (adaptation). When the interruption is longer (>1 s), the current perception is stabilized by sensory memory (persistence). We have examined the neural representations that fatigue and that persist by characterizing their respective selectivities for 3D shape. We used a variety of SFM shapes, including rotationally symmetric and asymmetric shapes, as well as shapes defined by solid volume and by surface only. In a sensory memory con-

Tuesday AM

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dition, different stimuli were presented in random order (Ton=[1,2.5] s), separated by blank intervals (Toff= 1 s). In a neural fatigue condition, prime stimuli (stabilized by depth and size cues) were presented for Tprime=10 s, followed by blank intervals (Toff= 0.4 s) and randomly chosen probe stimuli (Tprobe= 1 s). Contradicting earlier reports [Maier et al., 2002, Curr. Biol.], we find that sensory memory is shape-selective: 3D rotation is more stable when the same shape (rather than different shapes) are presented successively (ANOVA p<10-5). Moreover, positive priming increases with shape similarity (r= 0.76, p<10-14). In contrast, we find no shape-selectivity for neural fatigue: 3D rotation is destabilized comparably by same and different shapes (ANOVA p=0.7). Instead, some probes are more susceptible to aftereffects (from any prime) than others. We conclude that the visual representations of SFM that are subject to neural fatigue are not identical to the representations that maintain a sensory memory. This conflicts with the view that the same neural mechanisms mediate both positive and negative priming effects in multi-stable perception [Noest et al., 2007, J. Vis.].

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52.16, *12:00 pm*

Neural Correlates of Binocular Rivalry as measured in fMRI are partially confounded by observers' active report Stefan Frässle[1,2](fraessle@med.uni-marburg.de), Jens Sommer[2], Marnix Naber[1,3], Andreas Jansen[2], Wolfgang Einhäuser[1,4]; [1]Neurophysics, Philipps-University Marburg, Germany, [2]Department of Psychiatry and Psychotherapy, Philipps-University Marburg, Germany, [3]Vision Sciences Laboratory, Harvard University, [4]Center for Interdisciplinary Research (ZiF), Bielefeld, Germany

When different stimuli are presented to either eye, perception alternates between distinct interpretations, a phenomenon dubbed binocular rivalry. Numerous recent imaging studies have attempted to unveil neural substrates underlying binocular rivalry. However, most rivalry studies are bedeviled by a major methodological constraint: access to observers' perceptual state typically relies on introspection and active report (e.g., by button presses). Here we ask to what extent the observed neural correlates of rivalry are confounded by such subjective measures. We here used two reflexes, the gain of the optokinetic nystagmus (OKN) and pupil dilation, to objectively and continuously map perceptual alternations for dynamic and stationary rivalry stimuli. Using these two objective measures during functional magnetic resonance imaging, we could, for the first time, control for confounding influences of active report and introspection on the neural activity during rivalry. In all conditions, rivalry stimuli were contrasted against identical stimuli presented to both eyes whose alternation rate was matched to the endogenous alternations during preceding rivalry trials. We find that, when observers are asked to actively report their percept like in standard binocular rivalry paradigms, our objective measures are consistent with report. In this active condition, both objective measures and button presses identify occipital, parietal and frontal areas to underlie the processing of binocular rivalry. Although the objective measures provide additional statistical power due to their continuous nature, these results confirm earlier studies. Importantly, however, when observers passively experience rivalry without reporting alternations, a different picture emerges: differential neural activity in middle frontal areas is absent, whereas activation in parietal and occipital regions persists. Our results question the popular view of a driving role of frontal areas in the initiation of perceptual alternations during binocular rivalry. Instead, we conclude that frontal areas are associated with active report and introspection rather than with rivalry per se.

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52.17, *12:15 pm*

Altered perceptual bistability in binocular rivalry through neurofeedback training of high order visual areas Jinendra Ekanayake[1](jineks7@gmail.com), Ged Ridgway[1], Frank Scharnowski[2,3], Joel Winston[1], Koush Yury[2], Nikolaus Weiskopf[1], Geraint Rees[1]; [1]Wellcome Trust Center For Neuroimaging, University College London, [2]Institute of Bioengineering, Swiss Institute of Technology (EPFL), [3]Department of Radiology and Medical Informatics – CIBM, University of Geneva

Neurofeedback using real-time fMRI (rtfMRI) enables voluntary control of activity within a target brain region. By subsequently testing how such voluntary control of brain activity affects perception or behaviour, it is possible to establish a causal link between brain activity and behaviour We hypothesized that neurofeedback training of higher order visual areas would lead to a change in conscious perception that can be measured using a binocular rivalry (BR) paradigm. To test this hypothesis, brain signals and perception were measured during binocular rivalry between face and house stimuli in ten participants. Participants were then separated into two groups and learned up-regulation of either the fusiform face area (FFA) or the parahippocampal place area (PPA) using rtfMRI neurofeedback.Following training, participants reported BR again, this time either with or without simultaneous up-regulation of one of the target brain regions. During post-training BR without up-regulation, a significant decrease in duration and switch rate of the 'untrained' percept (i.e. a house when they learned to increase activity in the FFA, or a face when they learned to increase activity in the PPA) was observed, with no significant change in the perception of the stimulus linked to the trained region. During BR with up-regulation, there was a further decrease in the duration and switch rate of the 'unmodulated' percept which was significant (i.e. a house while concurrently up-regulating activity in FFA following training on FFA up-regulation, or a face while concurrently up-regulating activity in PPA following training on PPA up-regulation). We conclude that voluntary modulation of high order visual areas using rtfMRI neurofeedback causes lasting changes of BR dynamics and behaviour.

Acknowledgement: Wellcome Trust

Attention: Temporal selection, tracking

Tuesday, May 14, 10:45 - 12:30 pm
Talk Session, Royal Ballroom 4-5
Moderator: Edward Vul

52.21, *10:45 am*

The development of a novel visuo-motor task for measuring visual attention L. J. B. Hill[1](LiamJBHill@gmail.com), J. H. G. Williams[2], L. Aucott[2], M. Mon-Williams[1]; [1]Institute of Psychological Sciences, University of Leeds, UK, [2]School of Medicine and Dentistry, University of Aberdeen, UK

Introduction: The abilities to sustain and divide attention, inhibit response and selectively direct visual attention are skills that predict academic performance levels in children. These skills are commonly impaired in individuals with Attention Deficit Disorders. To date, no standardised psychometric test is capable of objectively measuring these aspects of attentive performance with the brevity and detail required to ensure such a tool is viable as a population-level screening assessment. Methods: We developed a 15min visuo-motor task suitable for use with adults and children and measured attentive functioning using a tablet-screen computer. Participants tracked moving targets on the screen with a stylus under single-task (following one target) and a variety of dual-task conditions (following one of four simultaneously displayed moving targets and intermittently switching to track a different target in response to a secondary cue presented in the visual periphery). Results: Experiment 1 established that manipulation of attentional load on the cue-detection component affected adult's (19-50 years) and children's (8-12 years) accuracy and tracking variability. Experiment 2 revealed age differences between groups, even after adjusting for motor-control differences. In Experiment 3, outcomes on the task were validated against the Gordon Diagnostic System (a standardised test of sustained attention) and parental reports of children's attentiveness (measured using two standardised questionnaires). Experiment 4 found differences in strategy when completing the task, with the strategic differences dependent on task difficulty and whether or not a participant had a developmental disorder. Conclusions: These results suggest our visuo-motor task has great potential as a population level screening tool for objectively measuring attentive functioning and detecting developmental disorders. These results will be discussed with regard to ongoing data collection in a cohort of 13,500 children (Born in Bradford) where performance on our task can be related to genetic, health and educational data on the children and parents.

Acknowledgement: Medical Research Council

52.22, *11:00 am*

Cognitive processing of value-associated distractors: Electrophysiological evidence Risa Sawaki[1,2](r.sawaki@bham.ac.uk), Steven J. Luck[2], Jane E. Raymond[1]; [1]University of Birmingham, UK, [2]University of California Davis

Our sensory environment is replete with visual stimuli associated with positive or negative outcomes. However, such value-associated stimuli are often irrelevant for ongoing tasks. Although previous behavioral studies show that these stimuli may inappropriately capture attention, we know little about the underlying brain processes mediating these effects. To investigate this issue, we recorded event-related potentials (ERP) from healthy human adults who had first learned to associate three different colored squares with three different monetary outcomes (gain, no outcome, or loss). These stimuli were then viewed in a simple, speeded choice task. Four squares were arranged in a cross pattern around central fixation. Participants were asked to attend to the two squares on the vertical meridian and to ignore squares on the horizontal meridian. On target-present trials (20%), both vertically-located squares were colored and both horizontally-located squares were gray; the task was to maximize reward by choosing a color. Immediate feedback was given. On target-absent trials (80%) both vertically-located squares were gray, requiring participants to press a different key to indicate target-absence. On these critical trials, one horizontally-located square was gray and the other (distractor) was colored. Response time (RT) was expected to vary with the value association of the irrelevant distractor. Indeed, RT was significantly slower when the distractor color was associated with gain versus no outcome or loss. ERPs measured on these trials showed that gain-associated distractors induced greater cognitive conflict (as indexed by the anterior N2 component) and greater attentional deployment (as indexed by the N2pc component). A second study that made target absent trials more distinct from target present trials replicated RT and anterior N2 results but instead found attentional suppression (as indexed by the Pd) of gain-associated distractors. These findings suggest that cognitive processing of value-associated distractors involves both conflict monitoring and attentional control systems.

52.23, *11:15 am*

Why the self stands out: Self conditioning to sensory stimuli alters perceptual salience Glyn Humphreys[1](glyn.humphreys@psy.ox.ac.uk), Jie Sui[1,2]; [1]Department of Experimental Psychology, University of Oxford, Oxford UK, [2]Department of Experimental Psychology, University of Oxford, Oxford, UK

Human perceptual learning is associated with slow-acting changes in the perceptual salience of stimuli. Here we present evidence showing that, in contrast to this, conditioning of a self-label to sensory stimuli produces ultra-fast alterations in the perceptual salience of the stimuli, changing the associated neural response . Using this self conditioning approach, we had participants associate shapes with either themselves or a friend, over just a short run of training trials. Subsequently the shapes had to be identified in hierarchical (global-local) forms. We first demonstrated effects of perceptual salience produced by blurring the shapes (to enhance global salience) and by introducing color differences between high-contrast local shapes (to enhance local salience). Response efficiency was reduced when the target had low salience and the distractor at the other level had high salience. Strikingly, this effect of perceptual salience was replicated when the original shapes were 'tagged' by associating to the self – response efficiency to a shape associated with an unfamiliar person was reduced when the distractor was associated with the self. This effect was not found for stimuli conditioned to another familiar person (best friend). Using fMRI we showed that the presence of a self conditioned distractor also increased activation in the left posterior parietal cortex, linked previously to the suppression of perceptually salient distractors (Mevorach et al., J. Cog. Neurosci., 2010). The results show that the conditioning of self-related information to sensory stimuli rapidly modulates visual perception, and the effects are modulated using similar neural processes to the effects of perceptual saliency. The data are consistent with social context affecting the way we see the world.

Acknowledgement: Economic and Social research Council, UK European Research Council

52.24, *11:30 am*

Children with autism spectrum disorder demonstrate normal attentional preference for faces and normal attentional disengagement Jason Fischer[1](jason_f@mit.edu), Kami Koldewyn[1], Yuhong Jiang[2], Nancy Kanwisher[1]; [1]Department of Brain and Cognitive Science and McGovern Institute for Brain Research, Massachusetts Institute of Technology, [2]Department of Psychology, University of Minnesota

Visual attention is widely thought to be affected in autism spectrum disorder (ASD). Because attention determines what we experience, process deeply, and remember, early impairments of attention could have substantial consequences for the development of other perceptual and cognitive abilities. Here we use a naturalistic free viewing paradigm to test 45 children with ASD (age 5-12) and 40 typically-developing children matched in age and IQ on two key signatures of attention that have been implicated in autism: attentional disengagement, and preferential looking to faces. We find that attentional disengagement costs (i.e., longer reaction times to saccade to a new target when the original target remains present compared to when it disappears) are present in ASD but are not increased in magnitude compared to typical children. We further find that children with autism make faster saccades to new stimuli if they are faces as opposed to nonfaces, and the magnitude of this social preference is identical to that seen in typical children. Thus, in contrast to prior reports, our data indicate that neither of these classic signatures of attentional function is impaired in children with ASD. While such impairments may be evident in other conditions (for example, with dynamic stimuli), our data indicate that any such impairments do not reflect a general, across-the-board disruption of either attentional disengagement or preferential attention to faces.

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52.25, *11:45 am*

Pulsed re-sampling of cued object during 'inhibition of return': new behavioral evidence Huan Luo[1](luohuan@gmail.com), Kun Song[1], Rui-Huai Zhang[2], Ke Zhou[1]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Biophysics, Chinese Academy of Sciences, [2]University of Science and Techonology, China

Inhibition of return (IOR), referring to inhibitory aftereffect at previously cued location, has been generally attributed to discouraging attention from orienting back to the originally attended location. IOR lasts for several seconds, but the behavioral microstructure during this inhibitory course remains completely unknown. Here by using a time-resolved measure (sampling every 20 ms), we examined the fine spectro-temporal dynamics in reaction times (RT) on 40 human subjects in a pre-cuing paradigm. 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), and subjects were asked to discriminate the shape of the target as fast as possible. Consistent with previous pre-cuing findings, we observed the typical facilitation and IOR effects in early (SOA <0.3 s) and late (SOA > 0.3 s) interval respectively. Most critically, during IOR range when RT was grossly slower for cued than uncued condition, the RT simultaneously underwent a rhythmic oscillation around 10-20 Hz, and the cued condition initiated stronger 10-20 Hz power than uncued condition in a pulsed manner (~3 Hz). Further analysis demonstrated a coupling between high-frequency power and low-frequency phase, matched with previous electrophysiological findings, implicating a theta-mediated sampling behavior. Finally, such pulsed 10-20 Hz power difference diminished when the target occurred in different locations within same object, whereas typical facilitation and IOR effects remained intact, implicating a dissociation between space-based and object-based attention. In conclusion, our studies, by examining behavioral performance at higher temporal resolution, provide novel evidence that the cued object is not completely inhibited during IOR, but gets re-sampled by returned 10-20 Hz attentional pulse mediated by theta oscillation. Our results also support the essential role of brain oscillations in attentional operation.

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52.26, *12:00 pm*

What is the marginal advantage of extrapolation during multiple object tracking? Insights from a Kalman filter model Jonathan Flombaum[1](flombaum@jhu.edu), Sheng-hua Zhong[2], Zheng Ma[1], Colin Wilson[3], Yan Liu[2]; [1]Department of Psychological and Brain Sciences, Johns Hopkins University, [2]Department of Computing, The Hong Kong Polytechnic University, [3]Department of Cognitive Science, Johns Hopkins University

Intuitively, extrapolating an object's trajectory should facilitate visual tracking. This intuition has motivated several investigations into whether humans extrapolate when tracking multiple objects. Surprisingly, they appear not to, largely ignoring an object's motion, and implementing a low-level, spatial memory function instead. Why do humans appear not to extrapolate if extrapolation is beneficial? We address this question by interrogating its underlying assumption: that extrapolation is beneficial in the first place. Recent advances have characterized tracking mechanisms as implementing correspondence operations over noisy inputs of object positions, speeds, and bearings. With noisy inputs noisy predictions should emerge. What is the marginal advantage of extrapolation given noisy predictions? We used a Kalman filter model to answer this question, endowing it with perceptual limits in the range of typical human observers. Specifically, we tested the model with a range of spatial precision limits as well as a range of limits on how quickly it could sample inputs. We compared the model's performance to a nearly identical model that does not extrapolate. In Experiment 1, we found worse performance for a model that extrapolated relatively rigidly compared to one that did not extrapolate at all. In Experiment 2 we found negligible

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advantages for a model that learned to weight its own predictions, and that the model placed little weight (<15%) on extrapolation. Finally, Experiment 3 demonstrated that a simple model that does not extrapolate replicates a signature finding in the literature on human tracking: improved performance following a global interruption for objects that remain stationary, compared with objects that persist along stable trajectories. Together, the results explain the finding that humans do not seem to extrapolate when tracking multiple objects. In particular, given human perceptual limits, extrapolating from noisy inputs does not confer a marginal advantage.

52.27, *12:15 pm*

Multiple object tracking difficulty accounted for by an ideal observer Cory Rieth[1](crieth@ucsd.edu), Edward Vul[1]; [1]Psychology, University of California San Diego

Our ability to track multiple targets among distractors is influenced by the number of objects onscreen, as well as their speed, spacing, dynamics, and superficial features. Here, we compare human performance to an ideal object-tracking observer to predict individual trial difficulty and the influences of tracking manipulations. We measured the maximum object speed at which observers were able to maintain 75% accuracy while varying object spacing, number of distractors, object color fidelity, tracking duration, and motion smoothness. Additionally, we measured the performance of 250 observers on 100 fixed trial trajectories (across-trial variation in accuracy was highly reliable over observers, r=0.63). We then compared trial accuracy and speed-spacing tradeoffs to the ideal observer tracking under the same manipulations. The ideal observer tracks each object via a Kalman filter, conditioned on the correspondence of represented objects to onscreen objects (sampled via a particle filter). We fit one parameter corresponding to noise in perceived spatial position to achieve 75% accuracy averaged over the measured speed-spacing thresholds. With no further fitting, the same model captures the variation in difficulty across trials (correlation of model to observer accuracy: r=0.50) as well as across task manipulations. Notably, the model explained the counterintuitive effect of better performance in conditions with less predictable motion. Although we could capture much of the reliable variation in trial difficulty, the ideal observer failed to capture the pattern of errors within a trial. This suggests that the same resource limitations that are necessary to account for effects of the number of targets may also underlie the systematic object errors. In summary, we show that an ideal object-tracking observer provides a good account of the changes in performance due to task parameters like speed, spacing, number of distracters, and object motion, and also the reliable variation in difficulty across trials.

Tuesday AM

Tuesday Morning Posters

Perception and action: Locomotion, navigation

Tuesday, May 14, 8:30 am - 12:30 pm
Poster Session, Royal Ballroom 6-8

53.301 **Visually guided overtaking behavior understood in relation to the maximal acceleration of vehicle: an affordance-based approach** Numa Basilio[1](numa.basilio@gmail.com), Antoine H.P. Morice[1], Geoffrey Marti[1], Gilles Montagne[1]; [1]Aix-Marseille University, CNRS, ISM UMR 7287, France

Fajen [1] suggests that the affordance-based approach can explain how successful goal-directed behaviors are selected and regulated in accordance with our own action capabilities. We test such a hypothesis in a virtual driving simulator by investigating the influence of action boundaries of driven cars while overtaking. A previous experiment [2] reports that drivers use an informational variable based on the Minimum Satisfying Velocity (MSV) related to the maximum Velocity of the driven car (VMAX), in order to perform safe overtaking. However, the perception of overtaking possibility through the MSV/VMAX ratio cannot account for the influence of more relevant kinematics features of automobiles such as acceleration. We therefore challenged our previous proposition and assumed in this present experiment that a new perceptual variable, defined as the Minimum Satisfying Acceleration (MSA) divided by the maximum Acceleration of the driven vehicle (AMAX), would accurately inform drivers about overtaking possibilities. Two groups of drivers were asked to perform overtaking maneuvers, if deemed possible, by driving virtual cars with one of two AMAX values (2 m/s² or 3.5 m/s²). Twenty five overtaking situations were set-up by combining 5 MSA and 5 MSV values. Firstly, our results showed that overtaking frequency significantly decreases when increasing the MSA and MSV values and becomes null for all groups when extrinsic task constraints exceed group action capabilities for both groups of participants. Secondly, we were able to show the significant differences between the groups in an extrinsic scale (i.e., function of MSA and MSV) disappear when an intrinsic scale is applied (i.e., function of MSA/AMAX and MSV/VMAX). These results are identical to our previous findings [3], [4] and confirm that MSA/AMAX is a correct ratio to account for visually guided overtaking behavior. Future analyses will be designed to investigate how MSA/AMAX affordance can account for the regulation of overtaking.

Acknowledgement: Aix Marseille University

53.302 **Effect of travel speed on visual control of steering toward a target** Rongrong Chen[1](rainerrchen@gmail.com), Diederick Christian Niehorster[1], Li Li[1]; [1]Department of Psychology, The University of Hong Kong, Pokfulam, Hong Kong SAR

It has been suggested that travel speed influences the use of visual strategies for the control of self-motion. Here we systematically examined the effect of travel speed on the control of steering toward a target. The display (113°H×89°V) simulated a participant traveling at 2m/s, 8m/s, or 15m/s over a textured ground plane. Participants used a joystick to control the curvature of their travelling path to steer toward a target. Two viewing conditions were tested: in the target fixation condition, the participant's virtual gaze direction was fixed on the target which was placed 10° away from the center of the screen. The target egocentric direction was fixed during steering and was thus unavailable for steering control. In the heading fixation condition, the participant's virtual gaze direction was aligned with heading which was displaced 10° away from the center of the screen. The target egocentric direction changed during steering and was thus available for steering control. Across five participants, mean last second heading error of 10-s steering was similar for the two viewing conditions and decreased significantly from 4.7°±1.5° (mean±SE) to 2.6°±1.0° and 1.7°±0.7° as travel speed increased from 2m/s to 8m/s and 15m/s, respectively. The steering delay was significantly lower at all speeds when target egocentric direction was available for steering. As travel speed increased, observers showed a significant increase in the steering delay when target egocentric cue was available (177±48ms, 210±57ms, and 230±64ms for the three speeds, respectively) but a significant decrease in the steering delay when this cue was unavailable (627±38ms, 557±15ms, and 540±20ms for the three speeds, respectively). We conclude that while high-speed travel does not affect the use of visual strategies for the control of self-motion, people are more accurate and efficient in using optic flow for steering control when travel speed increases.

Acknowledgement: Hong Kong Research Grant Council, HKU 7480/10H and PF09-3850

53.303 **On-road steering is biased by asymmetrical optic flow** Georgios Kountouriotis[1, 2](georkoun@indiana.edu), Katy Shire[2], Callum Mole[2], Peter Gardner[2], Natasha Merat[3], Richard Wilkie[2]; [1]Department of Psychological and Brain Sciences, Indiana University, [2]Institute of Psychological Sciences, University of Leeds, [3]Institute for Transport Studies, University of Leeds

It has been argued that optic flow, the pattern of motion at the eye, is crucial for controlling locomotion. Insects are sensitive to the global pattern of optic flow and it has been shown that they often attempt to maintain flow symmetry when flying. The environments humans encounter, however, are often asymmetrical with different surface textures present in distinct regions of the scene. Previous research on humans has shown that temporal and spatial flow asymmetries can influence walking down straight corridors, but these effects are largely negated by the presence of a visible ground that indicates the path (i.e. splay information). To examine conditions more akin to those experienced when driving, we created a ground plane with three regions related to a visible bending road. The ground could have a distinct texture applied to the road, outside of the road bend, and inside of the road bend to create asymmetric flow field displays. Results showed that different textures on either side of a path did cause systematic errors in steering trajectories, broadly consistent with the reduction of flow asymmetries. This was also true when one region was static (either by removing the texture or counter-rotating the textured region to remove velocity vectors) with steering biased toward the static region. We conclude that spatiotemporal asymmetries can affect human processing of optic flow and lead to biased locomotor steering even when travelling on visible paths.

Acknowledgement: Georgios Kountouriotis was funded by the EPSRC UK for his doctoral training

53.304 **Differential effects of reduced contrast on perception of self-motion vs. object-motion** D. Alfred Owens[1](fowens@fandm.edu), Jingyi Gu[1], Rebecca Patterson[1]; [1]Whitely Psychology Laboratories, Franklin & Marshall College, Lancaster PA

Several studies found that the speed of moving objects and patterns appears to decrease when contrast of the image is reduced (the "Thompson Effect"), suggesting that drivers may underestimate their speed in foggy conditions. However, a recent study, conducted on the road, found that drivers did not experience this illusion when contrast was reduced with diffusing filters (Owens, Wood, & Carberry, 2010, Perception). We conducted a two-part experiment to examine the differential effects of reduced contrast on perception of object-motion vs. self-motion. For object-motion, participants matched the speed of rotating disks of variable contrast; for self-motion, they estimated the speed of travel perceived in video clips of driving on a country road. Like the Thompson Effect, our results showed the disks appeared to rotate more slowly when contrast decreased. This effect was not found, however, for estimates of speed in the driving videos. These findings suggest that different neural pathways mediate perception of self-motion vs. object-motion.

Acknowledgement: Franklin & Marshall College Committee on Grants

53.305 **Speed-matching strategy used to regulate speed in side-by-side walking** Zachary Page[1](zachary_page@brown.edu), William Warren[1]; [1]Department of Cognitive, Linguistic, and Psychological Sciences, Brown University

The collective behavior of human crowds may result from visually-guided interactions between neighbors, such as walking side-by-side. By modeling these local interactions we aim to explain emergent crowd behavior. Previously we investigated behavioral strategies use to control speed in side-by-side walking (VSS 2012); here we report more extensive analyses and test additional models. A participant and a confederate walked together across an open 12m x 12m room, while their head positions were tracked. The confederate was instructed to slow down or speed up mid-trial, whereas the participant was instructed to walk next to the confederate. Cross-correlation of confederate and participant speed profiles revealed significant coordination (mean r=0.79, delay=650 ms) compared to randomly selected virtual pairs (mean r=0.18). Six speed-control models were compared, sim-

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ulating the participant's acceleration on each trial by using the confederate's data as input: (a) distance model (median r=0.38), null the z-distance between the confederate and participant, (b) direction model (median r=0.21), null the angle between the visual direction of the confederate and the participant's sagittal plane, (c) speed model (median r=0.80), null the difference in speed between the participant and the confederate, (d) constant distance model (median r=0.61), reduce the z-distance between neighbors to a constant value, (e) linear combination model (median r=0.80), a weighted sum of the speed and distance models, and (f) ratio model (median r=0.52), a ratio of the speed and distance models. Thus, a simple speed-matching model best accounts for the human data; adding a distance term does not explain further variance. This result is similar to that for speed control in pedestrian following (Rio 2010, 2012), suggesting a general principle for the visual coordination of speed among neighbors in a crowd. Future work will investigate the visual coordination of heading direction.

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53.306 Interception of a speed-varying target: 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

Interception of a moving target appears to be based on the constant bearing strategy (CBS) (Chardenon, et al., 2002, 2005; Lenoir, et al., 1999, 2002), and 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 that is continuously updated by current information (Hayhoe, et al., 2005). We investigate this question by testing whether CBS is sufficient to account for interception of a moving target that changes speed. Participants walked in a virtual environment (12m x 12m) to catch a target pole (2.9m high, 8.0m distant) moving on the ground plane. Displays were presented stereoscopically in a head mounted display (63˚H x 53˚V, 60 Hz), and head position was tracked (60 Hz). The target's initial speed was 0.6 or 0.8m/s, and after 3s randomly changed speed by -0.3, -0.2, 0.0, +0.2 or +0.3m/s. Head trajectories on each trial were simulated using three models: (i) CBS was based on current information; (ii) CBS+RT added a fixed visual-locomotor delay of 400 ms (Cinelli & Warren, 2012); (iii) CBS+RT+Window incorporated an estimate of the target's position and speed based on their averages within a moving temporal window (0 to 1000ms) (Greenwald, Knill, & Saunders, 2005). Model performance was measured by the mean distance between human and simulated trajectories at each time step. The results indicate that the CBS model accounts for human trajectories as well as the CBS+RT and CBS+RT+Window models, except in the 0.8+0.3m/s condition. Adding RT significantly improved model performance in that condition, but varying the Window did not improve it further. The results suggest that CBS+RT is sufficient to explain interception of a speed-varying target without an internal model of the target's motion.

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53.307 Optic flow, heading and steering: 'joining the dots'

Richard Wilkie[1](r.m.wilkie@leeds.ac.uk), Georgios Kountouriotis[1,2]; [1]Institute of Psychological Sciences, University of Leeds, [2]Department of Psychological & Brain Sciences, Indiana University

Optic flow can be used by humans to determine their direction of heading as well as to control steering. Dot-flow displays have been widely used to investigate heading perception due to the potential they provide for various quantifiable manipulations (e.g. flow density and luminance) and findings from these experiments have been used to better understand the real-world control of steering. However, it is still unclear whether textures more akin to those in the real world are more informative than dot-flow when judging heading and controlling steering. It is also unclear whether the visual conditions that enable accurate heading judgments will necessarily support successful steering. To investigate this the accuracy of heading judgements were compared across dot-flow displays of different densities and luminance as well as to a photorealistic textured ground plane. In a separate experiment we measured steering performance towards an offset target in order to have a direct comparison between heading and steering performance under the same visual conditions. Our findings suggest that the bright, dense, dot-flow displays led to equivalent performance as the realistic ground texture both when judging heading and actively steering. Very sparse displays (with few low luminance dots) led to poor performance for both heading and steering tasks. Interestingly the intermediate dot-flow quality revealed conditions that led to accurate heading judgements but this did not translate to accurate steering performance. We conclude that heading perception should not necessarily be considered synonymous with successful steering control, since some visual conditions that support heading judgements that will not necessarily support steering.

Acknowledgement: EPSRC, UK

53.308 Accuracy of walking direction with and without visual feedback

Jeffrey Saunders[1](jsaun@hku.hk); [1]Department of Psychology, University of Hong Kong

Direction of self-motion during walking is indicated by multiple cues, including optic flow, non-visual sensory cues, and motor prediction. I measured the variability in walking direction with and without visual feedback, and tested whether visual and non-visual cues are weighted in an optimal manner. Open-loop walking in an immersive virtual environment was used to assess the accuracy of perceived walking direction. Observers walked toward a target 4m away either with no vision, or vision during the first 1m of walking. Three simulated environments were tested: target-only, target and textured ground, or target with textured ground and scattered posts. With no vision, variability in walking direction averaged 3°. Visual feedback during initial movement reduced variability to about 1.5°, regardless of visual environment. These results show that observers are capable of initiating movement toward a target with reasonable accuracy, but that even a limited amount of visual feedback significantly improves accuracy. Based on these measures, an optimal estimator would strongly weigh visual information. A second experiment measured the perceptual weighting of visual and non-visual cues. Optic flow specified a conflicting heading direction (±5°), and bias in walking direction was used to infer cue weights. Visual heading had a significant effect on walking direction, but the estimated visual weights were smaller than predicted (33-43% vs. 71%), and varied depending on the visual environment. Non-visual information appeared to have more influence than expected given the relative reliability of cues.

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53.309 The relationship between performance on 2D shape perception and steering control

Bobby Nguyen[1](bhnguyen@wichita.edu), Yan Zhuo[2], Rui Ni[1]; [1]Psychology Department, Wichita State University, [2]Institute of Biophysics, Chinese Academy of Sciences

The spatial and temporal integration of visual information is important in motion perception and steering control. 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 optic flow in steering control is affected by low visibility conditions. In the current study we examined the effect of low visibility on spatial and temporal integration in a 2D shape perception (2DSP) task, which was further compared to a steering control task under reduced visibility conditions for younger adults. In the 2DSP task, participants were asked to identify a 2D shape resulting from kinetic occlusion information. Displays consisted of a 2D array of dots on both foreground shapes and the background. When the foreground object moves the disappearance and reappearance of background dots can be used to recover the object shape. Three versions of the 2DSP task were developed in which two of the three variables, the density, the lifetime, and the contrast of the dots, were manipulated. In each of the three versions, the threshold of one variable was measured, while the other two variables were manipulated. Twenty-one participants were randomly assigned to perform one of the three 2DSP tasks, and then completed a steering control task. In the steering control task, the visibility of the scene was manipulated by varying the quantity and quality of the optical flow information. We found that the correlation between the 2DSP task and steering control task under low contrast conditions depended on temporal integration. These results suggest that under reduced visibility conditions, temporal integration of visual information may play a larger role in steering control.

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53.310 Additivity of vection speed induced by fast and slow spatially-overlapped optical flows

Yuki Kawashima[1](kawashima@u.ip.titech.ac.jp), Kazuho Fukuda[1], Hirohiko Kaneko[1], Yasuki Yamauchi[2], Keiji Uchikawa[1]; [1]Department of Information Processing, Tokyo Institute of Technology, [2]Department of Informatics, Yamagata University

When two optical flows, expanding at different speeds, are overlapped in the visual field, the perceived vection speed cannot merely be predicted by our previous knowledge on the speed of the optical flows. In this study we investigated how the perception of the vection speed is affected when we encounter two expanding optical flows of different speeds. Two expanding optical flows, composed of 1000 random dots in total, were presented on

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a hemisphere-screen producing a wide visual field of 120 deg. The dots spread in 3D space with binocular disparity. We used the difference in speed between two optical flows as the experimental condition. In each condition, we varied the ratio of the numbers of random dots expressing two optical flows: fast and slow optical flow. Subjects estimated the perceived vection speed arisen from two optical flows. Fifteen subjects participated in the experiments. When the speed difference between two optical flows was small, the results showed that the perceived vection speed linearly increased with the ratio of the fast random dots. On the other hand, when the speed difference was large the slow random dots worked as a dominant cue to determine the vection speed. In order to explain these characteristics of vection speed when two optical flows coexist, we developed a non-linear model in which the vection speed was predicted by power summation of the individual vection speeds, which were derived in the condition where only one of the optical flows was presented. The ratio of the number of the random dots used to present each optical flow serves as a weighting factor. This model well describes the experimental results.

53.311 **The inverted vection caused by expanding/contracting random-dot patterns** Yasuhiko Saito[1](saitoy@psyche.mind.tohoku-gakuin.ac.jp), Kenzo Sakurai[2]; [1]Division of Human Informatics, Tohoku Gakuin University Graduate school, [2]Department of Psychology, Tohoku Gakuin University

The "inverted vection" is self-motion perception in the same direction as a foreground motion induced by the slowly moving foreground with an orthogonally moving background (Nakamura & Shimojo, 2000). Using expanding/contracting visual stimulus pattern that will not induce optokinetic nystagmus (OKN), we extended their study to (1) investigate whether the inverted vection in depth occurs or not, and to (2) reexamine their claim that the mis-registration of eye movement by suppression of OKN causes inverted vection (Nakamura & Shimojo, 2003). Observers wore a shutter goggle for stereoscopic vision, and viewed stimuli on a screen in 120 cm viewing distance. A fixation cross was always presented in the center of screen surface. The background pattern was perceived to be 15cm farther than the screen with rightward translating random-dots at a constant speed of 25 deg/s. The foreground pattern was perceived to be 15cm nearer than the screen with expanding/contracting random-dots at 5 constant accelerations (0.056, 0.223, 0.893, 3.571, 14.286 deg/sec2). Both foreground and background patterns were presented in the experimental condition. Only the foreground pattern was presented in the control condition. Observers performed key-press to report their perceived forward/backward self-motion, and the reported direction and duration of self-motion were recorded. In experimental condition, observers reported inverted vection when the foreground random-dots expanded/contracted slowly, and they reported ordinary vection when the random-dots expanded/contracted fast. In control condition, the duration of the self-motion sensation varied linearly with the speed of stimulus motion. The faster motion induced the stronger self-motion sensation in the direction opposite to the pattern motion. These results suggest that (1) the inverted vection in depth occurs, and (2) there must be some factor for the inverted vection other than the mis-registration of eye movement by suppression of OKN.

53.312 **Indoor Spatial Updating with Visual and Auditory Restriction** Tiana Bochsler[1](bochs001@umn.edu), Gordon Legge[1], Rachel Gage[1]; [1]University of Minnesota, Twin Cities

Spatial updating refers to the ability to keep track of one's position and orientation in an environment. Does visual (and auditory) perception of the size and shape of an indoor space facilitate spatial updating? How are people with impaired vision hindered in spatial updating? To begin addressing these issues, we tested 19 normally sighted young adults in several sensory deprivation conditions- artificially reduced acuity (mild blur: 20/135, or severe blur: 20/900), severely restricted field (dia = 8 degrees), and blindfolded with or without environmental auditory cues. Subjects were guided by an experimenter along short, three-segment paths in seven rectangular enclosed spaces (6 rooms and one corridor). Turning angles were non-orthogonal and the lengths of the path segments ranged from 3 to 9 ft. Each path began at the entry to the space and the subject was instructed to drop a place marker (beanbag) at the end of the first route segment. At the end of the route, subjects estimated the length and width of the space, and the distances and directions to the entry point and place marker. Vision status (but not presence or absence of auditory cues) affected performance on estimating space dimensions and the distances to the entry and place marker. Subjects performed significantly better with blur than on the blindfolded and field restriction conditions, $p < .05$. But vision status did not aid direction estimates of the entry and place marker, with mean absolute errors averaging 20 to 30 degrees. These results suggest that visual perception of room context has more impact on the distance component of spatial updating than the orientation component. Performance with high acuity and severe field restriction was no better than blindfolded performance, raising the possibility that people with very narrow fields may have as much trouble with spatial updating as people who are blind.

Acknowledgement: NIH grant EY017835

53.313 **Human Strategies Used to Navigate a Real-World 50-Foot Diameter 11-Arm Radial-Arm Maze** Michael K. McBeath[1](m.m@asu.edu), Leslie C. Baxter[2,1], Itamar S. Grunfeld[2,1], Bryan W. Camp[1], Sarah E. Mennenga[1], Gene A. Brewer[1], Heather A. Bimonte-Nelson[1]; [1]Department of Psychology, Arizona State University, [2]Department of Neuroimaging Research, Barrow Neurological Institute

Introduction: This study examines individual differences in navigational strategy to test and translate between active spatial reasoning models in human and rodent research. We built a real-world, 50-foot diameter, 11-arm walk-through Human Radial-Arm Maze (HRAM) to parallel the Rodent Radial-Arm Maze (RRAM). Methods: 157 participants performed the HRAM and cognitive tests. The HRAM required participants to traverse all 11 arms and recover money hidden under mats at the end of each arm with the fewest number of repeat errors. Participants were not allowed to use strategies of simple ordered chaining of arms or of every second arm. Participants were classified by self-reported use of navigational strategies, including use of external cues. Results: The accumulation of arm-repetition errors over time was similar to RRAMs, but consistent with a higher memory capacity. We found two primary strategies: (1) Systematic procedural heuristics (repeatedly crossing over to opposing arms, or complex chaining such as traversing every third arm), and (2) Unsystematic, brute-force memorization (patterns that relied on remembering features and global orientation cues). The 43% who used systematic heuristics made significantly less errors than the 57% who relied on brute-force memory. Those using external cues (48%) revealed that our two principal behavioral strategy categories did not correspond well with classic navigational strategy dichotomies like allocentric, map-based representations versus egocentric, landmark-based representations. For example, Strategy 1 can be achieved via either allocentric or egocentric representations, and Strategy 2 can be coded from either allocentric or egocentric perspectives. Nevertheless, testing humans in similar real-world environments as rats provides a foundational tool to translate models of spatial cognition and reasoning across species. Conclusions: The HRAM resulted in two behavioral classes of strategies, systematic heuristics versus brute force memory. The HRAM is a useful, ecologically-valid instrument for testing functional cognitive, memory, and navigational principles that translate between rodents and humans.

Acknowledgement: Funded in part by the Arizona Alzheimer's Association

53.314 **Development of spatial orientation and path integration in immersive virtual reality** Marko Nardini[1](m.nardini@ucl.ac.uk), Karin Petrini[1], Hey Tou Chiu[2], Celia Foster[3]; [1]Department of Visual Neuroscience, UCL Institute of Ophthalmology, UK, [2]UCL Division of Psychology and Language Sciences, UK, [3]UCL Division of Biosciences, UK

Although there are major changes in spatial cognition in the first years of life, spatial abilities continue to develop significantly through mid-childhood (e.g. Nardini et al, Current Biology 2008). Research with adults using immersive virtual reality allows for precise cue control, and for use of sensory conflicts to study interactions between cues. Here we asked whether immersive virtual reality using a relatively lightweight (1.3kg) headset is feasible for developmental research. In Experiment 1 we studied how observers use two distinct kinds of information about the shape of a virtual room – wall lengths and wall distances – to relocate a hidden object. Observers experienced a virtual environment displayed using a stereoscopic headset (nVisor SX111) whose movement was tracked and kept in register with the virtual space. Unlike toddlers, who are sensitive only to distances (Lee et al, Cognition 2012), adults used both wall distances and wall lengths to relocate objects. However, a 10-year-old child tested on the same task found wearing the headset to be fatiguing and did not complete the study. In Experiment 2 we piloted a method for studying cue integration during path integration. Observers completed a triangle with different information available in the outward walk: non-visual only (in the dark), visual only (playback of walking, while the observer is standing still), or both. Adults completed the task and showed differences across conditions consistent with the availability of different cues. A different 10-year-old child was tested, this time using a harness built to transfer the weight of the headset to the back while allowing for normal head rotation. This child completed the study with no difficulties and

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showed errors at the lower end of the adult range. This indicates that with suitable modifications, immersive virtual reality is a feasible method for studying novel aspects of spatial development in mid-childhood.

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53.315 When is visual information about obstacle size needed to step over an obstacle?

Melissa Parade[1](melissa.parade@gmail.com), Brett Fajen[1]; [1]Rensselaer Polytechnic Institute

When humans walk over rough terrain, the trailing limb is moved over obstacles on the ground without immediate visual information about the obstacle. That is, by the time the trailing limb begins its step, the obstacle has already passed from the field of view. Nonetheless, the trajectory of the trailing foot is precisely tuned to the location and dimensions of an obstacle being crossed. In this study, we investigated when visual information about an obstacle's dimensions is needed during approach to successfully guide the trailing limb over the obstacle. The experiment was conducted in an immersive virtual environment (VE) viewed through a head-mounted display. The positions of the head and both feet were tracked by a motion capture system. Subjects walked toward a goal initially located 5 away, and stepped over a box-shaped virtual obstacle on the ground along their path. The obstacle was initially located 4 m away and varied in dimension, by height and depth. Throughout most of the approach, the obstacle was replaced by a narrow line on the ground at the front edge of the obstacle, providing information about its location but temporarily removing information about its dimension. Information about obstacle dimension was briefly made available at one point during the approach: before walking was initiated or when the subject was three steps, two steps, or one step in front of the obstacle. Analyses focused on the effects of the availability of information about obstacle dimension on measures of precision and performance, which reflect the sufficiency of the visual information presented with respect to obstacle crossing. Initial testing suggests trailing foot trajectories are best tuned to obstacle dimensions when the information is available after the approach begins but before one step ahead of the obstacle.

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53.316 Perceived Hill Slant and Obesity: Perception Does Not Care about How You Feel

Mila Sugovic[1](msugovic@purdue.edu), Jessica Witt[2]; [1]Psychological Sciences, Purdue University, [2]Psychology Department, Colorado State University

According to the action-specific perception account, perception of space is influenced by the energetic costs required to perform an action. As a result, action abilities are restricted by the physical characteristics and limitations of the perceiver. As such, changes in an observer's reaching ability (Witt et al., 2005) or the ability to pass through an aperture (Stefanucci & Geuss, 2009) have an effect on perceived space, such as distance and width. Other work has also demonstrated that perceived hill slant is influenced by one's ability to walk up a hill; hills appeared steeper to people carrying a heavy backpack, those who are elderly or in poor physical fitness (Bhalla & Proffitt, 1999). However, these experiments have not made the distinction in terms of whether action-specific effects are influenced by actual ability and/or beliefs about ability. In the current experiment, we examined the effect of obesity on perceived hill slant. Among people who struggle with obesity, there exists a naturally occurring dissociation between beliefs about body size and actual body size (Truesdale & Stevens, 2008). Seventy-three subjects of various weight classification groups, including normal weight, overweight and obese, made visual estimates of the slant of a hill. Participants also provided evaluative, perceptual and self-report measures of their beliefs about body size as well as actual body size measurements such as weight, body mass index (BMI), and percent body fat. We found that actual body size influenced perceived hill slant such that greater BMI, body fat, and weight resulted in larger visual hill slant estimates. Furthermore, we found that beliefs about body size do not affect perceived slant, illustrating that perceived space is influence by an observer's actual body size regardless of a person's beliefs about body size.

Acknowledgement: NSF

Motion: Depth, higher order

Tuesday, May 14, 8:30 am - 12:30 pm

Poster Session, Royal Ballroom 6-8

53.317 Integrating information from invisible signals: the case of implied motion

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One key aspect of visual awareness is that it consists in an integrated experience, in which different features of objects (e.g., color, shape) cannot be perceived independently from each other. Accordingly, it has been proposed that consciousness must somehow relate to the capacity of the brain to integrate incoming sensory signals into a unified percept. This implies a lower level of integration for stimuli that are perceived at a subliminal, nonconscious level. However, this hypothesis has been challenged recently by empirical results revealing that incongruence between invisible objects and their backgrounds can still be detected, which suggests that visual awareness may not be necessary to detect semantic incongruence in visual scenes. Here, we asked whether nonconscious integration applies to other visual properties, independent of incongruity detection. We tested whether motion direction can be extrapolated from static stimuli implying motion (e.g., a picture of a horse running towards the left), both in the presence and absence of perceptual awareness. Relying on adaptation to motion, we found that visible - but not invisible – implied motion was processed such as biasing the perception of moving-dots. This suggests that only visible implicit motion can activate direction-selective circuits involved in the processing of real motion. Nevertheless, this negative result in the invisible condition does not imply the absence of nonconscious integration for implied motion, as we found in another experiment that invisible stimuli implying motion could still elicit repetition priming effects. We conclude that spatial integration applies to invisible signals implying motion, and that the involvement of real motion circuits after adaptation to implied motion results from post perceptual processes which only occur with perceptual awareness.

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53.318 Noise plaids reveal differences between motion and disparity computations

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Unidisparity plaids (in which one of two gratings has zero disparity) elicit short-latency disparity vergence responses (DVRs) that can be used to study how the brain extracts pattern disparity. Similarly, unikinetic plaids (in which one of the two gratings is static) elicit short-latency ocular following responses (OFRs) that can be used to study pattern motion. A close comparison of these results reveals differences in the pattern computation (DVRs are maximal when the two gratings have the same spatial frequency, which is not the case for OFRs). To investigate this further we measured, in three human subjects, DVRs and OFRs to a novel unidisparity/unikinetic plaid composed by summing two 1-D random line patterns. For the DVR, the zero-disparity noise pattern was replaced with a binocularly uncorrelated noise pattern, which abolished the responses to pattern disparity. For the OFR the stationary grating consisted (equivalently) of a new noise pattern on every frame, but this produced a response in the same direction as a stationary noise pattern. We also summed a correlated noise pattern containing disparity with an anticorrelated noise pattern at zero disparity. This reversed the direction of the pattern component in the DVR. When we studied the OFR with a two-frame motion stimulus containing an anticorrelated stationary component, there was no appreciable response in the pattern direction. However, with careful selection of parameters in stimuli containing many successive frames, we were able to observe reversed pattern responses when the contrast of the stationary pattern alternated between frames. These experiments demonstrate responses to pattern disparity/motion even in stimuli where an "Intersection of Constraints" is not well defined. An explanation based on channels narrowly tuned for spatial and temporal frequency is possible, but the differences between responses to disparity and motion indicate that a single explanation cannot be applied to both systems.

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53.319 Motion pop-out is determined by extra-retinal coordinate

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It is well known that moving targets pop out against stationary distractors in visual search displays. However, motion can be defined relative to the body (spatiotopic), or to the other stimuli (object-based) as well as in retinal coordinate, but the relative contribution of these different coordinate systems in visual search is not known yet. To clarify this point, we evaluated pop-out in a display where the target- and distractor- motions were defined by different coordinates. The stimulus consisted of 4 or 8 gratings patches (H1.3xV8.7 deg) placed on a gray background (H13xV8.7 deg) with a fixation point at the center. The gratings had randomly assigned orientation (45 or 135 deg). They were either stationary or moved. When they moved, they

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moved either upward or downward all together within the envelope. Motions defined by different coordinates were created by manipulating combination of stationarity and motion of gratings, background and fixation. For example, if fixation is moved together with the grating motion when the target is moving and distractors are stationary on the screen, the target becomes stationary and distractors become drifting on the retina. Using this logic, we examined the contribution of each coordinate system on pop-out phenomenon. Reaction times were measured for detecting a moving target among stationary distractor or a stationary target among moving distractors. It was found that the target pops out regardless of defining coordinates. In addition, there was an intriguing asymmetry. A target drifting in spatiotopic and object-based coordinate among retinotopically drifting distractors was detected faster than a target in the opposite combination, indicating advantages of spatiotopic and object-based motions in visual search. These results are consistent with our previous findings on the perceptual dominance in binocular rivalry (Nakayama et al., VSS 2012), and suggest that saliency of visual motion predominantly depends on extra-retinal information.

53.320 **Color updating on the apparent motion path**

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In long-range apparent motion, when a static object is presented at two different locations successively, one perceives its motion across these locations. When the objects presented at the two locations differ in shape, observers perceive a gradual shape change across the locations. In contrast, the interpolated color along the motion path abruptly changes from the color of the first stimulus into that of the second, suggesting no gradual feature updating for color during apparent motion (Hidaka et al., 2011; Kolers & von Grunau, 1976; Souto & Johnston, 2012). Here we report that a color, categorically distinct from the colors at the initial and terminal positions of apparent motion, can be interpolated as the intermediate percept on the path of apparent motion. Two blue (at the initial position) and green (at the terminal position) Gaussian blobs were repeatedly presented in a bistable quartet sequence. Perception of horizontal or vertical motion is possible at any given moment, and subjects were cued to see only one of the two possible directions in each trial. A colored target was briefly presented at the mid-point of either the left or right vertical motion paths within the final motion cycle and subjects reported on which motion path the target appeared. The results showed that subjects' target detection was impaired when the color of the target was "in-between" the initial and terminal stimulus color (cyan) as well as when it was the color of the terminal stimulus (green). This selective impairment disappeared when horizontal motion was seen, therefore the target was no longer on the path of apparent motion. This suggests that color may be also gradually updated during apparent motion, consistent with the previous findings using shape.

53.321 **Constraints on dynamical evolution of motion perception**

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In their 2007 paper, Kanai, Sheth, and Shimojo demonstrated that observers were less sensitive to transient changes in moving objects if these changes occurred after the object had been in motion for >300ms. They posited that this was due to a shift from processing motion as individual frames to a gestalt percept. They further proposed a model in which spatiotemporal receptive fields align in response to the direction and speed of motion present over a time period of ~200ms. We sought to further test and extend these findings by examining the effects of repeated practice (does practice facilitate the establishment of the gestalt percept?) and motion path changes (does trajectory uncertainty disrupt the spatiotemporal receptive field) on participants' ability to detect changes in a moving stimulus. Results indicated that with repeated practice, participants still showed a decline in the ability to detect transient changes in moving objects over time. However, this decline became attenuated with practice. Thus repeated exposure seems to weaken rather than strengthen the gestalt mode of perception. We also found that uncertainty in the motion trajectory did not improve transient change detection after 300ms or more of motion, as might be suggested by the previously proposed model. These findings suggest top-down factors related to practice and stimulus uncertainty likely contribute to the process of moving objects becoming gestalt percepts. Further, they call for an update to models based on the delayed alignment of spatiotemporal receptive fields.

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53.322 **Angular motion discrimination thresholds in amblyopic non-human primates and their implications for motion decoding**

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Goal: Amblyopia is a developmental vision disorder characterized by a loss of monocular spatial acuity. In addition to acuity deficits, amblyopes show decreased sensitivity to visual motion in random dot kinematogram (RDK) displays. Previous studies from our lab show particular impairment for fine spatial and long temporal offsets – slow speeds – on a 180-degree left-right direction discrimination. Physiological data from area MT in amblyopic macaques show that neuronal motion encoding deficits do not fully account for these impairments, suggesting a deficit in motion decoding. Coherence thresholds for different angular motion discriminations can be used to elucidate visual motion decoding. Small changes in coherence threshold as discrimination angle decreases suggest optimal decoding, whereas large increases in coherence threshold at fine discrimination angles reflect inefficiencies in decoding. Methods: To explore amblyopic motion decoding deficits, we used a two-AFC direction discrimination task with 3-5 test angles ranging from 10 to 90 degrees from vertical. For a single patch RDK, the animals' task was to indicate whether motion was to the right or left of vertical on each trial. A coherence threshold was measured for each test angle for each eye of seven amblyopic macaque monkeys (3 strabismic, 3 anisometropic, 1 unknown etiology). Results: Across the range of test angles, threshold coherence was elevated for the amblyopic eye relative to the fellow eye. This effect was less pronounced amongst our anisometropic amblyopes. While threshold coherence increased at fine discrimination angles, there was no evidence of a difference in the rate of increase between the two eyes. Conclusion: This pattern of deficits argues against, but does not completely rule out, a specific motion decoding deficit. Alternatively, these results can be explained by input deficiencies and/or increased neural noise downstream.

53.323 **Lower visual field advantage in multiple object tracking is mediated by a non-attentive motion mechanism**

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It has been reported that the performance for multiple object tracking (MOT) is higher in the lower visual field (LVF) than in the upper visual field (UVF, He et al., 1996). However, this LVF-advantage disappears when ISIs are inserted to apparent motion stimuli for MOT (Kanaya et al., VSS2005). These results suggest that the LVF-advantage can be accounted for the asymmetry in performance of first-order motion. To clarify this point, in this study, we examined the LVF-advantage with second-order stimuli. If first-order mechanism is responsible to the LVF-advantage, it should disappear with second-order stimuli. In Experiment 1, MOT stimuli defined by second-order attributes (contrast or motion) were presented either in UVF or LVF, and ISI was varied in 5 steps between 0 and 133.3 ms. A clear LVF-advantage was found at shorter ISIs, but it decreased as ISI increased, and disappeared beyond 100 ms. These results indicate that the mechanism that is responsible for the LVF-advantage is a low-level motion mechanism that is affected by ISI, but is not the ordinary first-order mechanism that is blind to second-order stimuli. In Experiment 2, the relationship between the LVF-advantage and attention was examined by using a dual-task method. Participants performed MOT in UVF or LVF and RSVP task (letter detection task) simultaneously. MOT stimuli were defined by one of the three attributes (luminance, contrast or motion), and two ISIs, 0 and 100 ms, were used. It was found that, when ISI was 0 ms, the performances in LVF were not affected by performing RSVP task, and the LVF-advantage still existed regardless of attributes, but the performance declined in the other conditions. These results strongly suggest that a non-attentive, lower-level motion mechanism that is different from the ordinary first-order mechanism mediates MOT in LVF.

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53.324 **Depth perception in color-interlaced stereoscopic 3D displays**

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Most stereo displays in everyday use employ temporal interlacing—temporally alternating presentation—to deliver different images to the eyes. This yields a temporal disparity between the left and right eyes. The brain interprets this as a spatial disparity thereby yielding a distortion in perceived depth (Mach-Dvorak effect). We asked whether this effect can be minimized by using color interlacing to present images to the eyes. In the first half of

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a frame, the green channel is presented to the left eye and the red and blue channels to the right eye. In the second half, the channels are reversed: green to right eye, red and blue to left. With a desaturated stimulus, both eyes are stimulated in both half frames, so luminance variation is greatly reduced. If the visual system computes disparity from luminance, color interlacing should significantly reduce depth distortions. If it computes disparity in part from chromatic information, two objects at different depths should be perceived, one caused by temporal disparity in green and the other caused by the opposite disparity in red and blue. We performed psychophysical experiments to determine how color interlacing affects the Mach-Dvorak effect. The stimulus consisted of disks rotating on a circular path. The plane of rotation was nominally frontoparallel, but when depth distortion occurred, it appeared slanted. We added a disparity gradient to eliminate the perceived slant and that gradient quantified the distortion. We presented different colors, varying in hue and saturation. When the exchanges were isoluminant, no depth distortion was observed. When they were non-isoluminant, distortion was observed and its magnitude was proportional to the luminance change. The results show that disparity is measured from luminance variation and that display protocols that minimize the luminance variation at each eye yield reduced distortions in perceived depth.

53.325 **Roles of perspective and pursuit cues in the disambiguation of depth from motion parallax** Marcus Mahar[1](marcus.mahar.1@gmail.com), Gregory DeAngelis[2], Mark Nawrot[1]; [1]Center for Visual and Cognitive Neuroscience, Department of Psychology, North Dakota State University, [2]Department of Brain and Cognitive Sciences, Center for Visual Science, University of Rochester, NY

While there is abundant psychophysical and neurophysiological evidence for an extra-retinal pursuit signal that disambiguates perception of depth from motion parallax (MP), we investigated the possible role of perspective information in disambiguating MP, both alone and in combination with pursuit. Dynamic perspective cues were generated with a random-dot plane that rotated (CW or CCW) about the vertical meridian, into or out of the screen. Such a dynamic-perspective stimulus could provide information about change in eye orientation relative to the scene, a variable needed to compute depth from MP (Nawrot & Stroyan, 2009). Can this dynamic perspective disambiguate the perceived depth-phase of an ambiguous MP stimulus? Which cue determines perceived depth when perspective and pursuit are in competition? Observers maintained fixation at the center of a MP stimulus surrounded by the perspective plane and reported perceived depth-phase of the MP stimulus. In Condition 1, rotation of a square perspective plane, with visible edges, disambiguated depth for most observers (average performance = 85%), although there was considerable variation across observers. In Condition 2, rotation of a large perspective plane that filled the screen, obscuring the plane's edges, had a substantially weaker disambiguating effect (average = 65%, range 50-80%). These results suggest that dynamic perspective can disambiguate depth for some observers. The difference between conditions 1 and 2 suggests that the transforming edges of the perspective plane play a larger role than the relative motion of dots within. In Condition 3, when perspective and pursuit were combined congruently, perceived depth was in near perfect agreement with these cues. When perspective and pursuit were in conflict, some observer's percepts were dominated by pursuit, but other observers showed an asymmetry depending on the direction of pursuit. Together, these findings demonstrate that both perspective and pursuit can contribute to perception of depth from MP.

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53.326 **Are we blind to three-dimensional acceleration?** Arthur J. Lugtigheid[1](lugtigheid@gmail.com), Robert S. Allison[2], Laurie M. Wilcox[3]; [1]Centre for Vision Research, York University, Toronto, Ontario, Canada, [2]Department of Computer Science and Engineering, Centre for Vision Research, York University, Toronto, Ontario, Canada, [3]Department of Psychology, Centre for Vision Research, York University, Toronto, Ontario, Canada

Accurate information about three-dimensional (3D) motion is essential for interception. Being able to detect changes in the speed of motion is potentially important, as approaching objects are unlikely to maintain constant velocity either by intent, or because of the force of gravity or friction. However, evidence from the interception literature shows that acceleration is not taken into account when judging time-to-contact from looming (i.e. retinal expansion). These data may reflect a curious insensitivity to 3D acceleration, a possibility that has received little empirical attention. As a first step towards a better understanding of this apparent lack of sensitivity, we assessed discrimination thresholds for 3D velocity changes. Observers viewed animations of an approaching object undergoing an increase (acceleration) or decrease (deceleration) in its simulated approach speed over the trial. The stimulus was a thin outline disk that was viewed monocularly, such that looming was the only available cue to motion in depth. On each trial, observers discriminated acceleration sign. We measured psychometric functions for three interleaved average speeds. To discourage observers from using non-relevant cues (e.g. due to regularities in the stimulus and correlations between variables) we randomized the simulated starting and ending distance. Our results show that observers were able to detect acceleration in depth, but their thresholds were very high (about a 25-33% velocity change). While precision did not depend on average velocity, there was a velocity-dependent bias: observers were more likely to report that the object accelerated for higher average approach speeds and vice versa. Thus, observers were sensitive to the acceleration of an approaching object under minimal cue conditions, but they could not completely dissociate speed and acceleration. We will discuss which signals could support monocular discrimination of 3D acceleration and produce the bias we found. Furthermore, we will extend these experiments to consider stereoscopic 3D acceleration.

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53.327 **Manual depth estimation for binocular disparity and motion parallax** Zachary Leonard[1](Zachary.Leonard@my.ndsu.edu), Mark Nawrot[1], Keith Stroyan[2]; [1]Center for Visual and Cognitive Neuroscience, Department of Psychology, North Dakota State University, [2]Mathematics Department, University of Iowa

Measurement of a subjective depth percept is an interesting psychophysical problem for which a variety of techniques have been developed. Here we compare perceived depth from motion parallax (MP) using manual depth estimation (MDE) to estimates previously obtained using an inter-cue-comparison, forced-choice technique (Nawrot et al., 2011, VSS). Observers indicated the perceived magnitude of line length or depth magnitude with the distance between the thumb and index finger, which was measured with a computer-recorded linear potentiometer. Stimuli were viewed binocularly, at 36, 54 and 72 cm, through a Stereographics Z-screen that provided both stereo separation and monocular viewing of the translating motion parallax stimuli. In Condition 1, observers gave MDEs for lines lengths between 0.5 and 6 cm. In Condition 2, observers gave MDEs for perceived depth - the peak-to-trough distance - of a random-dot stimulus depicting a vertically oriented corrugated surface. Stimulus depth was specified with either binocular disparity (1 - 24 min) or motion parallax (M/PRatio: 0.04 - 0.24). Overall, MDEs were variable, with extraordinarily large standard deviations. Comparing mean MDEs to physical line length generated regression lines with slopes between 0.4 and 1.0. The mean slope was 0.75 for all viewing distances. Comparing MDEs to expected stereo depth gave an "over-estimate" at 36 cm viewing distance (slope =1.10), but an "under-estimate" of depth as viewing distance increased (slope = 0.83 for 54 cm, and 0.65 for 72 cm). Johnson (1991) reports a similar trend. MDEs for MP showed a similar change with viewing distance. Compared to the expected values from Nawrot et al. (2011), MDEs over-estimated depth at 36 cm (slope = 1.38) and 54 cm (1.06) and under-estimated depth at 72 cm (slope = 0.93). We conclude that MDE has high variability but linear trends using mean MDE values provide similar estimates to cue comparison techniques.

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53.328 **Velocity constancy for familiar and unfamiliar objects** Andrés Martín[1](andres.mrtn@gmail.com), José Barraza[1,2]; [1]Instituto de Investigación en Luz, Ambiente y Visión ILAV - CONICET, [2]Departamento de Luminotécnia, Luz y Visión DLLyV - UNT

To explain that people can easily perceive physical instead of retinal speed, psychophysicists have proposed the temporal frequency hypothesis. The hypothesis is well suited to answer why an observer does not use the raw retinal speed measurement to decide about the velocity of objects in its field of vision. It also explains how the retinal speed signal can be processed to obtain an estimation of the object's physical speed, and why the distance does not matter in this processing. However, the hypothesis cannot explain why the algorithm seems to work well for cases in which distance and size vary coherently between them, and why object's familiarity biases the estimation of speed. In this work we present a conceptual model that captures the features mentioned above, and it is qualitatively capable to account for most psychophysical data, including a new experiment in which the observers had to compare the motion of familiar (basketballs and tennis balls) and unfamiliar objects. The experiment consisted in presenting to the observers movies containing basket and tennis balls and a white circle of the same size of the balls (control condition). The movies were presented on two CRT monitors. There were two main conditions namely, the one in which test and reference were displayed at the same distance, and the other, in which the test was displayed 3.6 times further away than the reference. 3.6 corresponds to the size relation between a basket and a tennis balls. A 2IFC paradigm with the method of constant stimuli was used to measure the point of subjective equality (PSE). Results show that the temporal frequency hypothesis cannot explain the perception of speed of familiar objects. In this case, speed seems to be scaled by using the prototypical size of the objects.

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53.329 **Perception of bidirectional transparent-motion requires a bimodal population response** Mark Edwards[1](mark.edwards@anu.edu.au), John Greenwood[1,2], Alyssa Morse[1], Carlos Cassanello[1]; [1]Research School of Psychology, ANU, Canberra, Australia, [2]Laboratoire Psychologie de la Perception Université Paris Descartes

The perception of bidirectional transparent motion involves the detection of two global directions within the same spatial region. It has been proposed that the neural population activity mediating this percept depends upon the angular separation between the two directions: bimodal activity-peaks for large angular differences and broad uni-modal for angles below 90o (Nature Neuroscience 2000, 270-276). This model is based upon the average tuning bandwidths of V5/MT cells. This means that unimodal population activity can underlie the perception of both uni- and bi-modal motion, and the proposed model does not state how the visual system could differentiate between the two. It would be simpler if transparency was always represented by bi-modal activity and uni-modal activity always indicated uni-directional motion. This could be the case if a subset of V5 cells, that have tighter tuning bandwidths, mediate motion transparency. We sought to determine the underlying population response via adaptation to transparent motion with various angular separations and the subsequent pattern of elevation in unidirectional motion thresholds. Stimuli consisted of either global-plaid or global-Gabor stimuli, which consists of multiple static apertures that contain either plaids or Gabors, respectively (JoV 2009 1-25). The minimum angular separation between the motion directions required to perceive transparency was established and adaptation was conducted at sub-threshold, threshold and supra-threshold (but below 90o) angular separations. In order to tap the population activity at the global-motion level, the apertures in the adapting and test stimuli were in different locations. Sub-threshold angular separations resulted in a uni-modal pattern of unidirectional threshold elevation while threshold and supra-threshold angular separations resulted in bimodal patterns of threshold elevation. The results support the notion that the perception of transparent-motion requires bimodal activity at the global-motion level.

53.330 **Computation of high-order correlations underlies edge-polarity selective motion processing** Justin Ales[1](justin.ales@gmail.com), Damon Clark[1], James Fitzgerald[1], Daryl Gohl[1], Marion Silies[1], Thomas Clandinin[1], Anthony Norcia[1]; [1]Stanford University

Visual motion is a critical behavioral cue. Contemporary neural models estimate motion by computing pairwise space-time correlations in light intensity. Moving natural scenes, however, contain more complex correlational structures. By simulating motion using natural scenes, we show that specific third-order correlations resulting from asymmetries in above- and below-mean regions of the visual scene contain useful information about motion. Moreover, motion estimation models that utilize odd-ordered correlations are able to distinguish between light and dark edges, something that 2nd order models cannot. Given that this information exists in moving natural images, we asked whether third-order correlations are estimated in a manner that distinguishes moving light edges from moving dark edges. First, to isolate light- and dark-edge specific neural responses, we used novel stimuli that separately manipulated motion direction and edge polarity. Using these stimuli and Steady-State Visual Evoked Potentials, we demonstrated that humans exhibit adaption that is specific to the combination of edge direction and edge polarity. Second, to isolate perceptual sensitivity to high-order correlations, we used 3-point "glider" stimuli that contain no net 2-point correlations. These stimuli separate the motion information contained in 3rd and higher-order correlations from that specified by 2nd-order correlations and they produce a percept of motion. To test for the connection between these high-order correlations and edge-polarity specificity, we first adapted participants to moving light and dark edges and then measured psychophysical sensitivity to the 3-point "gliders". We found that this adaptation modulates the perception of 3-point gliders. Our results thus indicate that a computation of high-order correlations underlies edge-polarity selective motion processing.

Face perception: Experience and learning

Tuesday, May 14, 8:30 am - 12:30 pm

Poster Session, Orchid Ballroom

53.401 **Time Course of Person Recognition in a Naturalistic Environment** Carina A. Hahn[1](achahn30@gmail.com), Eric Hart[1], Kate Flanagan[1], P. Jonathon Phillips[2], Alice J. O'Toole[1]; [1]School of Behavioral and Brain Sciences, The University of Texas at Dallas, [2]National Institute of Standards and Technology

Visually-based person recognition is studied most commonly using static images of faces. We studied how recognition accuracy and confidence evolves as a person approaches from a distance in a natural viewing environment. We familiarized participants with 30 people, using multiple video clips showing head rotation, smiling, talking, and walking. To test recognition, participants viewed 8s videos that began with a full-body view from approximately 13.6 meters and continued as the person approached the camera, veering off at the end of the clip. This allowed for a close view of the face only at the end of the video. Specifically, faces subtended approximately .36 x .54 degrees VA at the start point of the video and 2.55 x 3.31 degrees VA at the closest point to the camera. On half of the trials, participants responded (old/new) as soon as they were confident of their judgment (free response trials). On the remaining trials, participants made recognition judgments at three equally spaced time points in the video (multiple response trials), using a 5-point scale (1: sure old to 5: sure new). For the free response trials, known people were recognized accurately throughout the video. RTs were distributed normally around a mean RT of 5054 ms, when the person was approximately 3 meters from the camera. Across all time points, correct recognition of known people occurred faster (i.e., when they were farther away from the camera) than correct rejections of unknown people ($t(118) = 2.94$, $p = .004$). The multiple response trials indicated a linear increase in recognition accuracy and confidence over time ($p < .01$). Finally, to examine the recognition process qualitatively across videos, a cluster analysis was conducted on measures derived from pooled participant responses. This revealed diverse response patterns, indicating that in naturalistic settings, recognition evolves in a variety of ways.

53.402 **Fast and Famous: Looking for the fastest speed at which a face can be recognized** Emmanuel J. Barbeau[1](emmanuel.barbeau@cerco.ups-tlse.fr), Gabriel Besson[1], Gladys Barragan-Jason[1]; [1]Centre de recherche Cerveau et Cognition, Université de Toulouse, CNRS-UMR 5549, Toulouse, France

Introduction: Face recognition is supposed to be fast. However, the actual speed at which faces can be recognized remains unknown. To address this issue, we report two experiments run with speed constraints. In both experiments, famous faces had to be recognized among unknown ones using a large set of stimuli to prevent preactivation of features which would speed up recognition, hence they assessed what we call "bottom-up recognition". Methods: In the first experiment (31 participants), recognition of famous faces was investigated using a go/no-go task. In the second experiment, 101 participants performed a highly time constrained recognition task using the Speed and Accuracy Boosting (SAB) procedure (Besson et al, in press). Results: Results of both experiments converge and indicate that the fastest speed at which a face can be recognized is around 360-390 ms (minimum reaction time). Discussion : Such latencies are about 100 ms longer than the latencies recorded in similar tasks in which subjects have to detect faces among other stimuli. We discuss which model of activation of the visual ventral stream could account for such latencies. These latencies are not consistent with a purely feed-forward pass of activity throughout the visual ventral stream. An alternative is that face recognition relies on the core network underlying face processing identified in fMRI studies (OFA, FFA and pSTS) and reentrant loops to refine face representation. However, the model of activation favoured is that of an activation of the whole visual ventral stream up to anterior areas, such as the perirhinal cortex, combined with parallel and feed-back processes. Further studies are needed to assess which of these three models of activation can best account for face recognition.

53.403 **Variable use of the face and body in person identification** Allyson Rice[1](acr097020@utdallas.edu), P. Jonathon Phillips[2], Alice O'Toole[1]; [1]The School of Behavioral and Brain Sciences, The University of Texas at Dallas, [2]National Institute of Standards and Technology

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The human face usually provides reliable information for identifying someone. When illumination and expression variability make it impossible to identify a person from the face, people use the body, but are unaware of doing so (Rice et al., 2011). The goal here was to examine humans' use of the face versus body for identification when the quality of identity information in the face varied. Participants matched identity in pairs of same-identity and different-identity images. Same-identity images were selected using state-of-the-art face recognition algorithms from an international competition, based on the algorithm-computed similarity of the faces in the pair. Image pairs were stratified into good, moderate, and poor groups, ranking from the highest (highly similar images of the same person) to lowest (highly dissimilar images of the same person) similarity scores. We compared identification accuracy for image pairs (n=60) digitally edited to include only the face or the body. Humans judged whether the pairs showed the "same person" or "different people". We found that people performed more accurately with the face than with the body ($F(1, 42)= 58.55$, $p <.0001$). Human performance mirrored the algorithm-generated face-quality stratifications, with match accuracy decreasing monotonically from the good, to the moderate, to the poor condition ($F(2, 84)= 98.86$. $p <.0001$). We also found an interaction between the information available (face versus body) and the image pair groups (good, moderate, and poor) ($F(2, 84)= 8.28$, $p <.0006$). This interaction indicated that as the quality of the identity information in the face decreased, the gap between identification accuracy for the face versus body likewise decreased. In summary, both the face and the body contribute to identification accuracy. The relative importance of the face versus body, however, can shift with the quality of information in the face.

53.404 **High-performing face recognizers use eye-eye distance and eye-nose distance more than low-performing face recognizers**

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It is widely understood that faces are recognized either holistically or configurally, in terms information that is spatially distributed across much of the face. Individuals with developmental prosopagnosia demonstrate profound difficulty when recognizing faces whereas "super recognizers" are individuals with exceptional ability to remember faces with very little effort (Russell & Nakayama, 2006). The current study explores face recognition in super recognizers in more detail, focusing independently on face discrimination ability and face recognition decision strategy using a two-part experiment. Face recognition ability was assessed using the Cambridge Face Memory Test (Duchaine & Nakayama, 2006) and participants who performed in the top 10% and bottom 10% were operationally defined as high- and low-performing face recognizers, respectively. In Part 1 of the experiment, we measured face discrimination thresholds for seven internal face dimensions (i.e. eye shape, nose-mouth distance, etc) using a 2-interval same-different task. Face stimuli were displayed in grayscale, and an adaptive thresholding procedure (QUEST) was used to measure the 79%-correct threshold for face discrimination. In Part 2 of the experiment, we measured face recognition strategy using a 3-alternative forced error (3-AFE) design, a modified 3-AFC, delayed match-to-sample task in which there is no correct answer (Schwartz & Chang, 2008). Distractors were calibrated using thresholds measured in Part 1 and each distractor varied in only one dimension from the target so participant response indicated the dimension with the least utility. Results show that high-performing face recognizers rely more on eye-eye distance and eye-nose distance compared to low-performing face recognizers. High performers also deemphasize eye shape and nose-mouth distance compared to low performers.

53.405 **Subjective self-assessment of face recognition ability is only weakly related to objective measures of face recognition performance**

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Recent studies have shown wide individual differences in face identity recognition ability, ranging from "super-recognizers" (Russell et al., 2009) to developmental/congenital prosopagnosia (DP) (Berhmann & Avidan, 2005). Cases of DP are often identified following their self-reports of poor face recognition abilities, and in many labs this is confirmed by performance on objective tests. However, there is currently no evidence that subjective reports of face recognition difficulty truly reflect objective difficulties (De Haan, 1999). Here we report four studies performed in different institutions, with a large sample of typical participants (total N=300) who were all tested for their objective abilities with the Cambridge Face Memory Test (Duchaine & Nakayama, 2006) and other complementary face matching and memory tests. Subjective ability was assessed through a questionnaire used as a diagnostic tool of DP (Kennerknecht et al., 2008) in three studies, while a novel questionnaire was used in another. Psychometric properties of each test were good (high internal consistency; range of scores), and the objective measures were all highly correlated with each other. Despite this, correlations between subjective and objective measures were not significant in two studies. Correlations were significant, but small, in the other two studies, in which participants could gauge their face recognition ability during an objective task prior to completing the Kennerknecht questionnaire, or included a more detailed questionnaire. Altogether, this suggests only a minimal relationship between one's self-evaluation of face recognition ability and objective measures of face recognition performance. These observations are problematic for the conclusions of studies that recruited so-called cases of developmental prosopagnosia based purely on subjective report. They also suggest that typical individuals have generally poor access to knowledge about their relative level of performance at face recognition, mirroring similar lack of insight into other perceptual skills that are not formally taught (e.g., color perception).

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53.406 **Reduction of the face inversion effect in adulthood following training with inverted faces**

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Inversion of the stimulus in the picture plane has long been known to dramatically impair face recognition abilities (Hochberg & Galper, 1967 ; Yin, 1969 ; Valentine, 1988). This lower performance for recognizing inverted relative to upright faces constitutes one of the most well known and robust behavioral effects documented in the field of face processing (Rossion, 2008). Here we investigated whether extensive training in adulthood at individualizing a large set of inverted faces could modulate the inversion effect for novel faces. Eight adult observers were trained for 2 weeks (for a total of 16 hours) at individualizing a set of 30 inverted face identities presented under different depth-rotated views. Following training, all participants showed a significant reduction of their inversion effect for novel face identities as compared to the magnitude of the effect measured before training, and to the magnitude of the face inversion effect of a group of untrained participants. These observations indicate for the first time that extensive training in adulthood can lead to a significant reduction of the face inversion effect, suggesting a larger degree of flexibility of the adult face processing system than previously thought. Participants of the study are currently being retested with novel upright and inverted faces about a year following their initial training. We expect to observe a similar inversion effect for novel faces as the one observed before initial training, indicating that the effects of training with inverted faces are relatively short-term.

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53.407 **Perceptual Attention to Features versus Traits May Affect How Faces Are Represented in Memory**

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Describing a face can benefit its subsequent recognition, but this "verbal facilitation effect" is not fully understood. The current experiment compared the effects of describing faces in terms of their features versus personality traits. Each participant viewed a single block of faces in one of three conditions: (a) half of the faces followed by a cue to verbalize features, and half by a cue to count backwards by 3's, (b) half of the faces followed by a cue to verbalize traits, and half by a cue to count backwards by 3's, (c) all faces followed by backward counting. In both description conditions, participants did not know which of the two tasks would be performed until after each face was removed from the screen. Describing features or traits resulted in equivalent verbal facilitation. However, faces followed by counting were recognized better in the feature condition than in the only-counting conditions. Faces followed by counting in the trait condition, on the other hand, were not recognized better than in the only-counting condition. This pattern suggests that preparing to pro-

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duce a featural description facilitates subsequent recognition of a face, even when the description is not overtly produced. Perceptual attention to features versus traits may affect how faces are represented in memory.

53.408 Experience with objects moderates the overlap between object and face recognition performance, suggesting a common ability

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Recognizing faces is a crucially important skill in our social environment. Recent work suggests that face recognition constitutes a special human ability that is relatively independent from domain-general factors such as general cognitive ability, motivation or attention. We present evidence questioning the distinction between face recognition and abilities to recognize other objects. Our data suggest that face and object recognition performance reflect a common ability that more generally supports the acquisition of skills in discriminating visually similar objects and patterns. We show that the overlap between face and object recognition depends on experience with objects. In 255 participants, we measured face recognition using the Cambridge Face Memory Test (CFMT), object recognition for 8 categories using the Vanderbilt Expertise Test (VET), and self-reported experience (EXP) for the 8 object categories plus faces. Overall performance on VET and CFMT showed a significant correlation (r(254)=0.36 p=.003), whereas EXP correlated with neither the CFMT (r(254)=-.02, n.s.) nor VET (r(254)=-.03, n.s.). However, in a multiple regression on CFMT, the interaction between EXP and VET was significant (t253 = 2.15, p =.03). At the extreme, for participants with EXP more than 2 SDs above the mean, the shared variance between CFMT and VET was 59% (corrected for reliability of tests: 73% (95 CI: 49.5- 100)). This is consistent with object and face performance tapping into a single domain-general ability, given enough experience. The existence of such a domain-general ability may have broad-ranging implications. Beyond influencing aptitude in social interactions, this ability would constrain performance in other domains, such as learning to play chess, identifying tumors in X-rays or MRI pictures, identifying fingerprints or reading airport security displays. Because many domains of human activity benefit from skilled perception, measuring individual differences that may explain variability separate from that accounted for by general cognitive ability could greatly increase predictions about performance.

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53.409 Experience Predicts Other-Race Effects for both Identification and Holistic Processing

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Same-race (SR) faces are identified better than other-race (OR) faces, and this other-race effect (ORE) is correlated with experience. SR faces are also processed more holistically than OR faces, suggesting one possible mechanism for poorer performance on OR faces. Recently, we showed that individuating experience predicts the ORE in holistic processing (Bukach et al., 2012). Although a few studies have shown a functional relationship between holistic processing and identification of SR faces, this has yet to be demonstrated in OR studies. Here, we investigate the functional relationship between OREs in holistic processing and face identification and its relationship to experience in a Caucasian population (N= 26). Subjects completed a 4-alternative sequential matching task and a composite task to measure holistic processing for both Black and Caucasian faces on different days. We also administered Walker & Hewstone's (2006) survey that assesses quantity and quality of OR experience, and questions to assess quantity and quality of OR contact both prior to University and currently. There was a consistent but nonsignificant pattern of negative correlations between the ORE in face identification and all experience questionnaires, with current quality of experience being the strongest and most reliable predictor (r = -.347, p = 052), and a consistent pattern of negative correlations between holistic processing and experience, with quantity of contact prior to University most predictive (r = -374, p = .035), indicating that experience decreases the other-race effect in both identification and holistic processing. We observed a marginally significant positive correlation between OREs for identification and holistic processing (r = .301, p = .094), suggesting that the two may be functionally related. This interpretation is tentative until confirmed with further data collection.

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53.410 Measurement of visual and semantic knowledge for cars and estimation of experience

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The study of individual differences in object recognition is complicated by experience. The ability underlying object recognition cannot be observed directly: it is expressed in performance, which is the product of ability and experience. For faces, experience is high and varies little, and performance therefore reflects ability. For object categories, experience may vary greatly and estimating ability requires precise quantification of experience. We recently found that the correlation between performance for objects and faces increases with self-reports of experience with objects (Gauthier et al., submitted). However, the reliability and validity of self-reports is difficult to assess. Here, we aim to estimate experience independently of self-report. We assume, based on research with faces, that visual ability does not correlate with fluid intelligence, and that the latter determines the acquisition of verbal knowledge. Accordingly, the shared variance between visual and semantic performance for a given domain should reflect experience, which we eventually plan to estimate through a bi-factor binary response confirmatory factor analysis. As a first step, we designed a test of verbal knowledge for cars, the Semantic Vanderbilt Expertise Test (SVET-car), in which subjects identify real car names among foils. In 174 subjects (100 male) the SVET-car was reliable (a=.89) and correlated with visual car performance (VET-car, McGugin et al., 2012; r=.416, p<.0001). Using multiple regression, we found independent contributions of the VET-car and the SVET-car to self-report of car experience, confirming that self-report may be problematic for assessing experience because one's impression of one's knowledge and performance may influence reports. The interaction between VET-car and SVET-car was significant in predicting self-reports of experience (p=.018), with VET-car a better predictor of self-reports for those with greater semantic knowledge of cars. Estimation of object experience through performance in visual and semantic tasks should help us assess underlying abilities in object recognition.

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53.411 Categorizing racially ambiguous faces as own- versus other-race influences how those faces are scanned

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Recent eye-tracking studies have revealed that own- and other-race faces are scanned differently, and this differential scanning is affected by observer ethnicity. Westerners scan the eyes of own- and other-race faces more than other face parts (Blais et al., 2008). In contrast, Chinese observers scan more the central (nasal) region of Chinese faces, whereas they scan more the eyes of Caucasian faces (Fu et al., 2012). To better understand the relation between categorization of a face as own- versus other-race and face scanning, we conducted two experiments with Chinese participants who had no direct interaction with other-race individuals. In Experiment 1, we morphed Chinese and Caucasian faces to produce 50%-50% racially ambiguous hybrid faces. Chinese participants first sorted the hybrid faces into Chinese or Caucasian, and were then asked to remember and recognize the faces. In addition, participants were also asked to remember and recognize 100% Chinese and 100% Caucasian faces. The results with the 100% faces replicated Fu et al. (2012): Chinese observers fixated more on the nasal region of the 100% Chinese faces and the eye regions of the 100% Caucasian faces. More importantly, when the hybrid faces were classified as Chinese, participants scanned more on the nasal region, whereas when the faces were categorized as Caucasian, participants scanned more on the eyes. In Experiment 2, participants first performed a categorization task of the hybrid faces. They were then given a surprise memory test. Again, when the hybrid faces were classified as Chinese, participants scanned more on the nasal region, whereas when the faces were categorized as Caucasian, participants scanned more on the eyes. The findings suggest that although physiognomic differences between Chinese and other-race faces engender differential visual scanning, participants' subjective categorization of face race plays an important role in driving nose-centric versus eye-centric patterns of scanning.

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53.412 **Increasing attentional competition and uncertainty: An ecological approach to the cross-race effect** Thalia Semplonius[1](thaliastroo@gmail.com), Catherine Mondloch[1]; [1]Psychology, Brock University

The other-race effect (ORE: better recognition of own-race faces) is typically studied by presenting faces sequentially to participants and testing recognition using an old/new task. In the real world, people encounter multiple faces simultaneously and in complex scenes and so other-race faces compete for attention. Preferential attention to own-race faces on a daily basis and increased uncertainty when recognizing others in the real world may magnify the ORE in comparison to the relatively small effects typically found in the lab. We compared own- versus other-race face recognition under two different study and test conditions (n = 20 Caucasian participants per group). Participants studied 32 faces (16 Chinese; 16 Caucasian) sequentially (2s per face) or in arrays (shown for 24s) comprising eight faces (four Chinese) and multiple household objects. Recognition was tested using an old/new sequential-presentation task or a "lineup" task in which the proportion of old versus new faces varied across trials. We hypothesized accuracy would be higher in the traditional task but that the ORE would be larger in the array task. The d' values were higher for own-race faces than other-race faces (p<.001). The magnitude of the ORE varied as a function of learning style (p=.03) but not testing style (p=.72). Surprisingly, accuracy was higher when faces were presented sequentially than in arrays and this effect was larger for own-race faces. Increasing presentation times of the arrays (40s; n = 20) did not alter this pattern of results. Our results suggest that even own-race faces are hard to recognize when they compete for attention with other stimuli (Mean d' = .67) and that perceptual expertise for own-race faces may be most evident under ideal (i.e., sequential) viewing conditions.

Acknowledgement: NSERC

53.413 **Adding years to your life (or at least looking like it): The form of age aftereffects in face adaptation** Sean F. O'Neil[1](seano@unr.edu), Amy Mac[1], Gillian Rhodes[2], Michael A. Webster[1]; [1]Department of Psychology, University of Nevada, Reno, [2]School of Psychology, University of Western Australia

Adaptation has been found to affect most of the perceived characteristics of the face. Yet the functional form of the aftereffects remains poorly defined because they are typically assessed only at a single level such as a category boundary. Age is unique among facial attributes in that observers can reliably quantify levels throughout the natural range of variation (by assigning an age in years). We took advantage of this to ask how adaptation to a given age altered the appearance of faces throughout the adult lifespan, to assess the actual pattern of the response changes. Observers assigned ages to 80 photographs of faces with physical ages ranging from 18 to 89, before or during adaption to a random sequence of 10 younger (30-38) or older (63-67) faces which were not part of the test set. Average settings across the 20 observers were highly correlated with physical age though slightly reduced in range (with of slope of ~0.85 for perceived vs. physical age). Adapting to the young or old set caused all faces to appear older or younger, respectively, by roughly a constant amount (~+2.5 yrs). The aftereffects were thus well approximated by simple additive shifts with little change in slope. Importantly, this included biases in the adapting age range itself, so that observers were not simply becoming less sensitive to the adapting level. These results suggest that at least for the attribute of age, the effects of adaptation are consistent with a global and linear renormalization of the dimension, and thus with a recentering of face space.

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53.414 **Differential Attentional Allocation and Subsequent Recognition for Young versus Older Adult Faces** Lindsey Short[1](ls08ts@brocku.ca), Valentina Proietti[2], Thalia Semplonius[1], Catherine Mondloch[1]; [1]Department of Psychology, Brock University, [2]Department of Psychology, University of Milano-Bicocca

Past studies examining the other-age effect, the finding that own-age faces are recognized more accurately than other-age faces, are limited in number and report inconsistent results. Here, we sought to examine whether attentional allocation for young versus older adult faces differs during learning and whether such differential allocation influences subsequent recognition. We presented faces in the context of naturalistic scenes that mimic how we encounter faces in the real world and manipulated task instructions such that only half of the participants knew there would be a memory test. Twenty-four young adults viewed eight scenes for 40 seconds each while their eye movements were recorded; each scene contained two young and two older faces. Half of the participants were told to form impressions of the people and places in the scenes, and half were told there would be a subsequent memory test. Participants then viewed 64 individual faces (32 novel; half young) and indicated whether each face was familiar or novel. Regardless of task condition, participants allocated more attention to young (26% of total viewing time) than older faces (21% of total viewing time), p <.001. Similarly, in both task conditions, recognition accuracy was higher for young (d' = 1.28) than older faces (d' = 0.60), p <.01. However, there was no correlation between the magnitude of the young adult recognition advantage and the magnitude of the young adult looking time advantage, r = -.09, p > .10. These results suggest that longer looking does not necessarily indicate deeper encoding of young faces and that the young adult recognition advantage may emerge as a function of early encoding during learning and be unrelated to subsequent attentional allocation. Older adults are currently being tested to determine if this effect is moderated by participant age.

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53.415 **Visual recognition of the "silent generation": Understanding the recognition advantage for young versus older adult faces.** Valentina Proietti[1](v.proietti@campus.unimib.it), Viola Macchi Cassia[1], Catherine Mondloch[2]; [1]Department of Psychology, University of Milano-Bicocca, [2]Department of Psychology, Brock University

Young adults recognize own-age faces more accurately than other-age faces, but less is known about the underlying mechanisms and there is inconsistent data concerning whether older adults show an own-age or a young-adult recognition bias. In Experiment 1 we tested young adults' (n = 20) ability to recognize upright and inverted young versus older faces in a delayed 2-alternative forced-choice (2AFC) task. We found a marginal advantage for young faces in the upright condition (p=.058) and a stronger inversion effect for young faces (p=.015), indicating greater use of face-specific processing strategies with young compared to older faces. In Experiment 2 we tested whether the young face processing advantage reflects greater sensitivity to identity cues in young faces. We blended 24 young and 24 old identities to create two average faces (one young, one old) and then morphed the average face with each original identity to create faces with different identity strengths (5 steps: 20%, 40%, 60%, 80%, 100%). In each of four blocks, young (20-30) and older (60-90) participants were trained to recognize a target face and then were asked to detect that target face or faces similar to the target (e.g., the 40% version) among other faces of the same age. Although young adults were overall more sensitive than older adults (p <.001), there was no effect of face age (p = .39), indicating that sensitivity to identity cues for both young and older adults does not differ as a function of face age in a target detection task. Accordingly, in Experiment 3 we replicated the 2AFC task at 60% identity strength and found that the processing advantage for young faces disappeared. Perhaps the own-age processing advantage in young adults reflects greater efficiency in building representations of multiple identities, this advantage is lost when identity strength is reduced.

53.416 **Searching for own- and other-age faces: evidence for the role of experience** Viola Macchi Cassia[1](viola.macchicassia@unimib.it), Lucia Gava[1], Emanuela Bricolo[1]; [1]Department of Psychology, University of Milano-Bicocca

Available evidence suggests that attention deployment is modulated by specific face traits, such as emotional expressions and face race, with an attentional advantage toward those faces that are less efficiently discriminated and recognized at the individual level (angry or other-race faces). In this study we aimed to extend previous evidence to a different face attribute –age–, which is known to modulate face discrimination and recognition in the form of an other-age deficit, which is mitigated or eliminated if experience with other-age faces occurs. We compared adults' search efficiency for own- and other-age faces in a visual-search task with adult and newborn (Experiment 1) or adult and child face stimuli (Experiment 2 and 3), in which age was the target feature, and participants were required to process age-specifying information in order to provide their responses. In Experiment 1 (N = 20) and Experiment 2 (N = 20) participants were selected for having limited experience with newborn and child faces, respectively; in Experiment 3 (N = 20) participants were preschool-teachers with at least 2 years of working experience with children. We found a search asymmetry in favor of the adult face in both Experiment 1 and Experiment 2, whereby non-experienced adults showed a larger increase in search time as a function of set size (steeper search slopes) for newborn (p <.001) or child (p = .015) faces than for adult faces. In contrast, face age did not modulate search efficiency of experienced participants in Experiment 3, since search slopes did not differ for adult and child faces neither on target-present nor on target-absent trials (p = .8). The results suggest that the influence of age on attention deployment parallels the effects that this face attribute has on face perception and recognition, and that both effects are experience-based.

53.417 **The Joint Influence of Expression Variation and Exposure Frequency on Face Recognition and Generalization: An ERP Study**
Gary C.-W. Shyi[1](cwshyi@gmail.com), Julia W.-J. Lin[1]; [1]Department of Psychology, Center for Research in Cognitive Sciences, and Advanced Institute of Manufacturing with High-tech Innovations, National Chung Cheng University, Taiwan

Our recent study showed that a relatively large number of exposures coupled with sufficient number of variation in expression can help created reliable representation of newly learned faces and put them on the trajectory of being transformed into familiar ones (Shyi & He, 2011). Here we examined the underlying neural mechanisms by recording ERP components for faces that were learned with either relatively large number (i.e., 24) or relatively small number of exposures (i.e., 12), while being subject to variation of a single expression or multiple expressions. The ERP results during learning showed that there were no differences in mean amplitude for N170 and N250 regardless whether faces were learned with a single vs. multiple expressions or with different number of exposures (12 vs. 24). However, those learned with 24 exposures exhibited shorter peak latency for both N170 and N250 than those learned with 12 exposures, suggesting differential strength of memory trace as a consequence of exposure frequency. During the subsequent test of recognition and generalization, the results of corrected recognition accuracy (i.e., Hit – FA) largely replicated our previous finding and showed that as exposure frequency increased, faces learned with greater expression variation yielded better recognition and generalization. Furthermore, the ERP results showed (a) a larger P1 component for 24 exposures than for 12 exposures, and (b) an interaction effect on N170 component where the difference in mean amplitude between single and multiple expressions increased as exposure frequency increased from 12 to 24, even though the overall negative deflection in amplitude was greater for the former than for the latter. Taken together, the ERP findings corroborate those obtained with behavioral measures, and unveil the neural correlates of the joint influence of expression variation and exposure frequency on face recognition and generalization.
Acknowledgement: National Science Council, Taiwan Ministry of Education, Taiwan

53.418 **Face animacy perception is species-specific**
Benjamin Balas[1](benjamin.balas@ndsu.edu), Kami Koldewyn[2]; [1]Center for Visual and Cognitive Neuroscience, North Dakota State University, [2]McGovern Institute for Brain Research, MIT

Observers are good at determining whether a face is real or not, and animacy is perceived categorically in human faces (Looser & Wheatley, 2010). Presently, we used high-level adaptation to determine if face animacy is represented in a category-specific fashion, or if the perception of animacy across face categories is supported by a common neural mechanism. We created four sequences of morphed adult faces that spanned a continuum between real and artificial appearance in increments of 10%. We recruited 56 observers to rate perceived face animacy before and after adaptation to (1) Adult faces, (2) Child faces, and (3) Dog faces. Pre-adaptation, participants viewed the test images in a randomized order for 1000ms each and provided ratings on a 1-7 Likert scale. In the adaptation phase, participants were adapted to an adult face (N=24), a child face (N=16), or a dog face (N=16). The use of real/artificial adapting images was balanced within each group, and adapting images were presented at twice the size of the test images to minimize low-level adaptation. Each participant's animacy ratings in both phases were fit to a logistic function, and after-effect magnitude was assessed using shifts in the point of subjective equality (PSE). We obtained significant aftereffects following adaptation to adult faces ($t(23) = 4.04$, $p = .001$) and child faces ($t(15) = 6.96$, $p <.001$), but not following adaptation to dog faces ($t(15) = -.48$, $p = .64$). In a follow-up task, we confirmed that within-species animacy aftereffects obtain when morphed dog images and dog adaptors are used ($t(15) = 2.15$, $p = .05$), suggesting that the lack of transfer between dog and human faces is not a function of the selected dog images. We conclude that the perception of animacy in face images is species-specific, but generalizes across age categories.
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Tuesday AM

Face perception: Disorders

Tuesday, May 14, 8:30 am - 12:30 pm
Poster Session, Orchid Ballroom

53.419 **Even you, greebles? Normal greeble performance in acquired prosopagnosia supports face specificity**
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A prominent account of face processing suggests that face recognition depends on generic mechanisms involved in processing object classes for which individuals have developed expertise. Many laboratory studies of expertise have used a multi-session training paradigm designed to develop expertise with computer-generated stimuli known as greebles. If the recognition of faces and greebles following training depend on the same mechanisms, impairments with faces should be accompanied by impairments with the acquisition of greeble expertise. Contrary to this prediction, we present two cases of acquired prosopagnosia who exhibit normal greeble learning. Florence (female, 29, with a right anterior temporal resection for epilepsy) and Herschel (male, 55, with right occipitotemporal lesions following several strokes) completed an eight-day greeble training procedure used in previous studies. Their accuracy and response times were similar to those of age-matched control participants. In addition, by the end of the training procedure, both Florence and Herschel fulfilled the criterion expertise researchers claim signals successful acquisition of greeble expertise: comparable response times for greeble recognition at the family and individual level. As expected, Florence and Herschel failed to match controls' learning profile in a follow-up training procedure with faces, demonstrating a dissociation between face and greeble expertise. In addition, Herschel's lesion disrupted his right fusiform face area (FFA) so his results show that greeble learning can occur without an intact FFA. In sum, our findings are inconsistent with claims from the greeble literature challenging face-specificity, and indicate that distinct mechanisms are used for face recognition and the object recognition processes used in greeble training procedures.

53.420 **Facial expression training improves emotion recognition and changes neural tuning in a patient with acquired emotion recognition deficits and prosopagnosia**
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Studies suggest that face discrimination training can ameliorate face identification and emotion recognition deficits in developmental visual disorders (e.g., prosopagnosia and autism spectrum disorders). In contrast, face discrimination training has yet to produce improvements in those with acquired identity and emotion recognition deficits, possibly because of more compromised cognitive/neural infrastructure in these cases. We offered face discrimination training to patient CC who developed severe identity and emotion recognition deficits following resection of an astrocytoma within the right fusiform and superior temporal gyri. We separately performed face identity training (DeGutis et al, 2007) and expression training (Tanaka et al., 2010) over a 2-year period and collected fMRI data before and after each training session, functionally localizing left OFA, FFA, and STS regions and collecting a measure of holistic neural tuning for faces (Harris & Aguirre 2010). Our initial attempt at training, focused on identity, was ineffective: after 4 weeks/30 hours of training, CC showed no behavioral improvements in identity recognition. In contrast, 9 months later we performed 4 weeks/30 hours of expression training and found significant improvements on self-paced emotion recognition tests (which persisted for several months) but not on tests of speeded emotion recognition. Interestingly, neural adaptation measures of face processing in the left FFA indicated part-based tuning before, and holistic tuning after, both training sessions. Although the functional significance of these neural changes after identity training is unclear (it is possible that changes in left FFA tuning were sufficient for behavioral improvements in emotion but not identity), together these results suggest that training-induced neural changes are possible in a very compromised face processing system. In sum, we show training-related emotion

recognition improvements in a patient with acquired emotion recognition deficits and suggest that these improvements may depend on slower to engage compensatory face processing mechanisms in the left hemisphere.

53.421 Varied behavioral profiles in children with developmental prosopagnosia reveal dissociations in the developing face processing system

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Developmental prosopagnosia (DP) is a neurodevelopmental condition characterized by severe face recognition problems that result from a failure to develop the visual mechanisms necessary for normal face processing. Although much work has been done to study DP in adults, little has been done to study it in children. The study of DP in children makes it possible to address unique questions regarding the organization and development of the face processing system. Specifically, by looking at the performance of children with DP on a variety of face and object processing tasks, cognitive dissociations can be identified that can speak to the functional organization of the face processing system. Looking at patterns of face processing impairments in the developing system can also provide information about when the mechanisms underlying normal face processing differentiate from each other during development. We used a battery of tests of face and object perception to document the behavioral profiles of children with suspected face recognition difficulties. Children performed tests of face memory, face perception, face detection, expression recognition, and gender discrimination, as well as object recognition tasks matched to the face tasks. General intelligence, acuity, and autistic tendencies were also assessed. Distinct phenotypes of DP emerged: Some children presented impairments on some, but not all face tasks, and performed normally on object tasks, suggesting face-specific deficits restricted to a subset face-processing abilities. Other children presented more widespread face processing deficits, performing poorly on all face memory and perception tests, yet normally on object tasks, indicating severe face-specific processing impairments. Another subset of children presented severe face and object processing deficits, indicating more general high-level visual impairments. These results provide evidence for dissociations of face processing abilities early in life and provide a basis for classifying different phenotypes of DP the developing face processing system.

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53.422 Functional neuroimaging and behavioural classification of a case of prosopagnosia with classic bilateral occipitotemporal lesions

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Background: The classic cases of prosopagnosia described by Meadows (1974) and Damasio et al (1982) had bilateral medial occipitotemporal lesions. While cases with right-sided lesions have been described since, the impact of such classic lesions on the face network and various aspects of face processing are unknown. Objective: We studied a patient with bilateral occipitotemporal infarcts including both middle fusiform gyri, to determine the impact of the lesions upon the face processing network on functional MRI, correlate this with results on a behavioural battery, and compare these to prior subjects with unilateral lesions affecting the right fusiform face area (FFA) and/or occipital face area (OFA). Methods: We used the dynamic face localizer in functional MRI to characterize the core face processing network. In a perceptual battery, we evaluated face recognition, face perception, face imagery, and semantic knowledge about famous people. The subject had an event-related potential study of the face-selective N170. Results: There was no activation of either right or left FFA, or left OFA, but sparing of both pSTS (posterior superior temporal sulci). He was severely impaired in discrimination of facial configuration and features, and impaired in car and handwriting recognition. He performed normally on face imagery and semantic knowledge of famous people. There was no face-selectivity in the right N170 response, and in fact showed a larger left N170 response to objects than faces. Compared to R-IOT4, who had a lesion of the right FFA, he had more difficulty with same-view matching of faces, and other within-class object recognition. Conclusions: The bilateral medial occipitotemporal variant of prosopagnosia, with loss of both FFA and the left OFA, is associated with severe deficits in processing facial structure, associated recognition impairments for other object classes, as well as loss of the N170 response in the right hemisphere.

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53.423 Caricaturing improves face recognition in simulated age-related macular degeneration.

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Age-related macular degeneration (AMD) damages central vision, leaving only blurred peripheral vision. This severely impacts face recognition and thus social functioning. Here, we explore whether face recognition could be improved in AMD, by manipulating the physical face image such that it better suits the perceptual mechanisms humans use to recognise facial identity. We enhance identity information in the face via 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. For high resolution (unblurred) face images, caricatures are better individuated than veridical faces. We replicate this caricature advantage. We then simulate early- through late-stage AMD by filtering spatial frequencies to mimic the appearance of a face at approximately 10° through 30° into the periphery, for a face sized as if viewed on a tablet computer held in the crook of the arm. Results show that the caricature advantage is present for even the most highly blurred images. Specifically, pairs of different-identity faces presented simultaneously are rated as more dissimiliar with increasing degrees of caricature; and in a face learning task, old-new recognition is improved at least for new faces. Remarkably, for 10° blur, caricaturing improves performance to 'normal' levels (i.e., equal to veridical unblurred faces). Finally, we explore the origin of the caricature advantage within the visual system. Some caricature advantage is present for inverted faces, and in observers of different race to the target faces. This argues at least part of the caricature advantage arises from mid-level shape vision, or possibly feature-level coding of faces that is less sensitive to orientation and race than whole-face coding. We conclude that properties of multiple stages of the visual system may be relevant to choosing image manipulations that improve face recognition in AMD.

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53.424 Electrophysiological Findings of Visual Attention Bias Away from Angry Faces in Patients with PTSD

Dhrasti Shah[1], Colin Cameron[2], Dylan Smith[3,4], Natalia Jaworska[1], Crystal Blais[5], Derek Fisher[6], Verner Knott[1,3,4,5], Charles Collin[1]; [1]School of Psychology, University of Ottawa, [2]Brockville Mental Health Centre, [3]Cellular & Molecular Medicine, University of Ottawa, [4]University of Ottawa Institute of Mental Health Research, [5]Carleton University, [6]Department of Psychology, Mount Saint Vincent University

Evidence from visual probe detection tasks suggests that anxious individuals exhibit biased (enhanced) selective attention to threat stimuli, such as angry and fearful faces. Attentional bias to threatening stimuli has been characterized by (1) facilitated attention to stimuli (vigilance), (2) difficulty disengaging attention away from stimuli, or (3) attentional avoidance of stimuli. The current study used event-related potentials (ERP) and behavioural performance measures to examine the effects of attentional bias towards ecologically threatening stimuli (emotional faces) in 18 post-traumatic stress disorder (PTSD) patients and 18 healthy controls during a dot probe task. Behavioural measures of target detection and the amplitude and latency of early (P100, N100) and late (P200, P300) ERPs were assessed during presentation of face pair displays and target probes. Processing of threat-face pairs did not reveal evidence of attentional bias in PTSD patients. Perceptual (P100) and cognitive processing (P300) of target probes following angry-neutral face pairs revealed evidence of attentional avoidance in the patient group. The P100 and P300 ERPs revealing avoidance patterns to angry-neutral face pairs also correlated with severity of PTSD symptoms and revealed an inverse correlation with severity of depression, respectively. The ERP results time-locked to the target-probe paralleled findings with performance accuracy. The present study provided no support for facilitated engagement to threatening visual stimuli in this sample of patients, instead showing that PTSD patients may exhibit an avoidance pattern to threatening stimuli that may be controlled by strategic mechanisms occurring at later stages of information processing.

Object recognition: Features, parts

Tuesday, May 14, 8:30 am - 12:30 pm

Poster Session, Orchid Ballroom

53.425 Independence Between Shape and Texture Processing in Single-Object but not in Object-Ensemble Perception

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Behavioral research has demonstrated that the shape and the texture of a single object can be processed independently of each other (Cant et al., 2008). Consistent with this behavioral finding, neuroimaging results have shown that an object's shape and texture are processed in distinct brain regions, with shape in the lateral occipital area and texture in parahippocampal cortex (Cant & Goodale, 2007). Meanwhile, objects in our environment are not always seen in isolation and there are ample instances in which multiple objects are grouped together as an ensemble (e.g. leaves on a tree). We recently showed that the processing of object ensembles also involves parahippocampal cortex (Cant & Xu, 2012) and that the shape and texture of ensemble elements are processed together within this brain region (Cant & Xu, VSS 2011). These neural data suggest that the independence seen between shape and texture processing in single-object perception would not be observed in object-ensemble perception. In the present study, we tested this prediction. Specifically, we examined whether observers could selectively attend to the shape of ensemble elements while ignoring changes in an unattended texture feature, and vice versa. Across five behavioral experiments, we replicated previous findings of independence between shape and texture processing in single objects, finding that changes in an unattended object feature did not affect the processing of an attended object feature. In contrast, we observed that changes in an unattended ensemble feature negatively impacted the processing of an attended ensemble feature, indicating that ensemble shape and texture are not processed independently, consistent with our prediction. Moreover, we found that processing ensemble feature changes more locally (similar to single-object processing) eliminated interference, whereas processing ensemble feature changes more globally produced interference. Taken together, these findings suggest that distinct cognitive and neural mechanisms are involved in single-object and object-ensemble perception.

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53.426 A hierarchical model of the early mammalian visual system that learns appropriate features for object recognition

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Biological vision systems use a complex hierarchical structure of features to represent the world. Lower level features (retina to V1) include intensity gradients and changes, oriented edges, motion, color, etc. For mammals, object classification performance greatly depends on both the base feature set and the hierarchical structure that combines them. Object classification becomes even more difficult in changing environments where the useful features for detecting and classifying a given object may change. We propose a model, based on the mammalian visual system, which learns a hierarchical structure to combine a set of base features which are used to detect and classify a specific object. The model continually adapts to handle changing environments and involves a two-stage process: potential objects of interest are identified in the first stage and passed onto a second which provides a behavioral reinforcement signal. The first stage uses parallel background subtraction models, one for each feature, combined via a weighted voting mechanism and produces a ranked list of potential objects. Feedback from the second stage adjusts the weights from each model using a modified instar learning law to lower both false positive and false negative rates. The result is a combination of basis features that are useful for detecting a specific object. We tested our model with an object identification task in a noisy environment. Simulation results demonstrate that learning an appropriate feature basis increases performance (true positive rate) three-fold (0.1 to 0.34) by selecting a set of 2/8 total features and seven-fold (0.1 to 0.7) by selecting a set of 12/134 total features. Learning occurred over tens of frames, enabling quick adaptation to changing environments. These results demonstrate that our model is able to learn to appropriately combine features and may provide insight into the biological structure used by the human visual system.

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53.427 Representation of object contour features in intermediate visual areas in the human brain

Mark D. Lescroart[1], Shinji Nishimoto[1], Jack L. Gallant[1]; [1]University of California, Berkeley

Vision is mediated by a set of hierarchically organized cortical areas that represent information at different levels of complexity. Peripheral visual areas represent simple image-level features such as oriented edges, textures and motion energy. Central visual areas represent the semantic categories of objects and scenes. Intermediate areas are thought to represent shape features (such as silhouette contours) that are critical for building up more complex representations from simpler features. However, because it is difficult to parametrize shape features in natural photographs, most studies of shape representation use simple objects on blank backgrounds. Consequently, intermediate representations of complex shapes in natural scenes are still poorly understood. To investigate this issue we used computer animation software (Blender) to render realistic artificial scenes that varied in color, texture, and lighting, as well as in object position, size, and semantic category. Human subjects viewed the rendered movies for 70 minutes while BOLD fMRI responses were recorded from visual cortex. We then computed contour features associated with objects (i.e., silhouettes and surface/depth discontinuities within objects) based on the virtual 3D world that generated each scene. We used these features as regressors in a voxel-wise modeling and decoding (VWMD) framework. VWMD estimates a set of weights for each individual voxel that reflect how specific features influence hemodynamic responses. Finally, we used a separate data set to test predictions of the fit models. We found that predictions of the object contour models were more accurate in V4 and lateral occipital cortex than were predictions of a simple motion energy model shown previously to provide good predictions in V1. Furthermore, predictions did not improve when additional regressors that reflected contours at surface/depth discontinuities in the background were included. Our results suggest that intermediate visual areas represent the contours of foreground objects in the natural world.

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53.428 The role of the type of local contour in global shape discrimination.

Gunnar Schmidtmann[1](gunnar.schmidtmann@gcu.ac.uk), Graeme J. Kennedy[1], Harry S. Orbach[1], Gunter Loffler[1]; [1]Glasgow Caledonian University, Vision Sciences, Visual Neuroscience Group

Subjects perform in the hyperacuity range when discriminating circles from Radial Frequency (RF) patterns: contours containing radial sinusoidal modulations. This high sensitivity results from integrating information across the entire contour. Points of maximum curvature have been implicated as a key feature in this integration process. To determine the role of local curvature in global shape processing, we measured curvature discrimination for complete contours (circles, RF3, 5 & 8; size=0.5deg; curvature=2.0/deg), isolated RF cycles and circular arcs (angular extents from 22.5-360deg). The task was to detect deviations from circularity (RF & isolated cycles) or the curve with higher curvature. For circular arcs, thresholds increase with increasing angular extent following a power-law relationship (slope = -0.56) but only up to 180deg (semi-circle). Extending the size further does not improve performance. Thresholds for discriminating circular segments (of half the angular extent of an RF cycle) were comparable to those for complete RF contours. Sensitivity for single RF cycles was significantly poorer than for complete RFs or circular arcs. Thresholds for RF arcs centred at points of convex contour maxima, contour minima and points of inflection showed no significant difference. Given that curvature thresholds for entire RF contours do not significantly exceed those for circular segments, one might speculate that RF computation is limited by detecting points of maximum curvature. This is, however, inconsistent with substantially reduced sensitivity for isolated RF cycles. Instead, results suggest that the signal of local curvature units elicited by RF patterns is degraded compared to circular segments and that global pooling of such sub-ideal local signals may explain the hyperacuity performance for these shapes. This reconciles an apparent paradox: RF sensitivity can be similar to that of isolated circular arcs and yet high sensitivity for RF contours results from global pooling of local information.

53.429 Representation of object parts and wholes in V2 modified by medial temporal lobe structures

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Recent research has demonstrated (a) that the perirhinal cortex (PRC) encodes complex object-level configurations of features, and (b) these representations participate in discriminating familiar versus novel configurations. The ventral visual stream is able to identify familiar object parts as such even in the face of PRC damage, although it cannot identify their configuration as correct or incorrect Barense et al. (2011). Here, we use fMRI to investigate whether extrastriate cortex in the intact brain a). is sensitive to the configuration of parts of familiar objects and b). covaries with activation in the PRC. Participants viewed peripherally presented silhouettes (nearest edge 4°) that portrayed familiar or novel objects. There were 3 types of silhouettes: familiar configurations (objects that exist in the real world); part-rearranged novel configurations (rearranged parts of the familiar configurations); and novel configurations created by (inverted part-rearranged novel configurations) (See figure 1). To our surprise, we found visual field asymmetries in the manner in which object parts were encoded in both V2 and the region of the medial temporal lobe (MTL) with which V2 activation covaried (see figures 2 and 3). When presented to the right visual field (RVF), familiar parts in their familiar rather than scrambled configuration evoked stronger activation in V2 and PRC (area 35). When presented to left visual field (LVF), however, this pattern of activation was reversed and covaried with activation BA 38. These data confirm that the V2 is sensitive to the configural status of familiar parts, but because the receptive fields of V2 neurons are large enough to encode object parts (2°) but not entire objects (6°), this sensitivity is likely modulated by feedback from structures within the MTL. We conclude that active perception of object configuration relies on both early visual cortex and structures within the MTL.

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53.430 **Time to wave goodbye to phase scrambling – creating unrecognizable control stimuli using a diffeomorphic transform.**
Bobby Stojanoski[1](bobby.stojanoski@gmail.com), Rhodri Cusack[1]; [1]Western University

To isolate the neural events associated with the recognition of visual objects from the events corresponding to the perceptual processing prior to object recognition, control stimuli are needed that contain the same perceptual properties as the objects, but are not recognizable. Traditionally, control stimuli have been generated using phase-scrambling, box scrambling, and more recently, texture scrambling. We show these methods yield poor control stimuli because they dramatically change basic visual properties (e.g., spatial frequency, perceptual organization) to which even the earliest stages of visual processing are sensitive. To overcome this limitation, we applied a new warping method, using a diffeomorphic transformation that preserves lower-level perceptual properties while removing meaning; we acquired norms for recognition at various degrees of warping (N=415 participants completed 15600 trials). We hypothesized that images warped using our new method will produce neural activity at pre-recognition stages along the visual hierarchy that is similar to the intact versions of these images. To test this hypothesis, we computationally modeled neural activity (using the HMAX model) for each distortion method and compared it to the intact version of the image at three stages along the visual system: simple and complex V1 cells, anterior areas corresponding to area V4, and inferior temporal cortex. Based on average neural output and the distribution of activity across simulated neurons, we found that "diffeomorphed images" were markedly more similar to intact images than any of the other distortion methods. Our results show that unrecognizable diffeomorphed images better match the fundamental visual properties of intact images, and therefore serve as more appropriate control stimuli in neuroimaging research. We suggest that diffeomorphed images should be used to disentangle the representation of perceptual and semantic object features during perception, memory and attention.

Acknowledgement: NSERC

53.431 **Monkey neuronal assemblies predict (across objects) human fMRI and behavior**
Chou Hung[1](ch486@georgetown.edu), Chang Mao Chao[2], Li-feng Yeh[2], Yueh-peng Chen[2], Chia-pei Lin[2], Yu-chun Hsu[2], Ding Cui[1]; [1]Dept. of Neuroscience, Georgetown University Medical Center, [2]Inst. of Neuroscience, National Yang-Ming University, Taipei, Taiwan

Complex systems (e.g. for object recognition) are classically explored via hierarchical computational models that are derived from principles of primary sensory cortex. Biological guidance for higher stages of these models remains poor, and existing approaches cannot bridge this gap. Single-electrode recordings do not reveal how neurons act as part of local assemblies, e.g. populations of neurons spanning ~500 μm grouped by tuning covariation and coincident spiking. Functional MRI is an indirect measure that blurs across multiple assemblies within each mm3 voxel. This problem of spatial scale is compounded by investigator-driven biases in stimulus manipulation, making it virtually impossible to find specific neuronal assemblies and circuits underlying the same complex feature computations across animals and species, or even to confirm feature-specific results across studies. We measured spiking assemblies in inferior temporal cortex, the last stage of the macaque visual object pathway, by combining precise mapping via multi-electrode arrays with precise measurement of assembly tuning covariation and coincident spiking. The assemblies were tuned to complex features in stimulus space, and these 'key features' enabled identification of the same feature assembly in another monkey via optical imaging. These monkey complex features also accurately predicted, across objects and in humans, fMRI patterns in lateral occipital complex and perception of a complex visual illusion. Altogether, this preliminary evidence suggests that a common library of complex visual object features, with common organizing principles and computations, is shared across individuals and across species.

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53.432 **The artist's advantage: better spatial and temporal integration of object structure**
Florian Perdreau[1,2](florian.perdreau@parisdescartes.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

Many artists spend thousand of hours analyzing object structures in order to render them accurately. Here we ask whether this extensive training affects visual processing, specifically the analysis of object structure. First, participants' drawing accuracy was assessed by comparing geometrical properties of their drawing to those of the original picture (Carson, Millard, Quehl and Danckert, 2012). We then used two tasks to evaluate the subjects' efficiency of integration of object structure: visual search to measure how this efficiency changed with eccentricity, and masking to examine the rate of temporal integration at the fovea. In the first experiment, objects were displayed around a central fixation dot and participants had to report whether a target, a possible object among impossible distractors or vice versa, was present. Fixation was controlled with an eye tracker. We varied the objects' eccentricity as well as their number, and object size was scaled with eccentricity. Despite the correction for cortical magnification, search performance decreased with eccentricity. However, there was a smaller decrease with eccentricity for subjects with better drawing scores ($r=-.89$, $p<.04$), suggesting more efficient processing of object structure in the periphery for these subjects. In the second experiment, a single object was centrally presented, followed by a dynamic mask. We varied object-mask SOA and participants had to report whether the object was structurally possible or not. The critical SOA at which performance reached 75% correct decreased with their drawing scores ($r=-.99$, $p<.001$), suggesting that more skilled subjects needed less time to encode and categorize object structure at the fovea. Taken together, these results suggest that more skilled individuals may call on faster central processing and a better peripheral integration of object structure.

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53.433 **Different neural processing of hole and no-hole stimuli in early stages of cortical and subcortical visual pathway**
Qianli Meng[1,2](neuroqianlimeng@gmail.com), Yan Huang[2], Ke Zhou[2], Ding Cui[2], Yuanye Ma[1,2], Lin Chen[2]; [1]Laboratory of Primate Cognitive Neuroscience, Kunming Institute of Zoology, Chinese Academy of Sciences, [2]State Key Laboratory of Brain and Cognitive Science, Institute of Biophysics, Chinese Academy of Sciences,

Growing psychophysical evidence supported that the extraction of topological properties serves as the starting point of the formation of an object representation, especially with an initial step being to compute the absence and presence of a hole feature within an object. However, what constitutes the neural substrates of this early perceptual difference of hole and no-hole is still an unsolved question. Our previous study had demonstrated that there exists a privileged detection of stimuli with holes in the absence of awareness compared with no-hole stimuli, which suggested that the hole feature maybe processed via a subcortical pathway which bypassed the cortical site of visual pathway. Using functional magnetic resonance imaging fMRI, present study investigated the neural responses of the early stages of cortical (lateral geniculate nucleus (LGN) and early visual cortex) and subcortical pathway (superior colliculus (SC) and pulvinar), when visibility of the hole and no-hole stimulus is greatly reduced by backward masking. We found that, for no-hole stimuli, the neural activity of lateral geniculate nucleus and early visual cortex (cortical pathway) decreased as

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the stimuli was rendered more invisible. In contrast, for the hole stimuli, a increased response was observed in superior colliculus, pulvinar (subcortical pathway) and early visual cortex though it's visibility was greatly attenuated by masking. The results indicate that a cortical route, via LGN and early visual cortex, is required to 'drive' a perceptual response of no-hole stimuli and in parallel, a subcortical pathway may possibly provide a route for processing the invisible hole stimuli. This distinct neural modulation of hole and no-hole stimuli may provide the possible neural mechanism for the perceptual difference between hole and no-hole stimuli that occurred early in the initial periods of the object representation.

53.434 **Action Influences Object Perception** David Chan[1](davidyt.chan@mail.utoronto.ca), Mary Peterson[2], Morgan Barense[1], Jay Pratt[1]; [1]University of Toronto, [2]University of Arizona

Proximal hand posture biases activity in the magnocellular (M) visual pathway (Gozli et al., 2012; Goodhew et al., in press). We tested whether this is due to having visual stimuli in the "action space" of the hands by making use of the finding that low spatial frequency images are rapidly identified through "gist" processing arising from the M-pathway (Kveraga, 2007). In Experiment 1, we paired low and high spatial frequencies images with either a proximal or distal hand posture and had participants indicate whether the objects were larger or smaller than a prototypical shoebox. Participants responded faster to low spatial frequency images paired with a proximal hand posture. No differences were found with distal hand posture. In Experiment 2, we manipulated proximal hand postures such that hands were either action oriented with palms in (palms toward the stimuli) or non-action oriented with palms out (palms away from the stimuli). In Experiment 3 we used one proximal hand posture (palms in) only but manipulated the type of visual stimuli such that they were either action oriented (easily grasped) or non-action oriented (not easily grasped). The results of Experiments 2 and 3 demonstrated that when action was primed (whether through hand posture or stimulus type) there was an advantage for low spatial frequency images. Overall, these experiments show that rapid "gist" object perception is due to M pathway activity, and that this processing is influenced by action-based hand positions.

Acknowledgement: NSERC

53.435 **How does the brain integrate banana with yellowness: The neural architecture of object colour knowledge requires left anterior temporal lobe** Rocco Chiou[1,2](roccochiou@gmail.com), Paul F. Sowman[1,2], Andy C. Etchell[1,2], Anina N. Rich[1,2]; [1]Department of Cognitive Science, Macquarie University, [2]Centre for Cognition and its Disorder, Macquarie University

The knowledge of typical colour (e.g., bananas are yellow) can influence successful object recognition. Most studies on the neural representation of object colour knowledge focus on whether knowledge and perception of object colour rely on overlapping neural substrates (the left fusiform gyrus/v4), with little research on the processing of colour knowledge beyond v4. Some recent studies suggest that the anterior temporal lobe (ATL) acts as a 'conceptual hub' that integrates different sensory attributes into an amodal representation, and is critical for semantic knowledge. In this study, we explore whether ATL plays a critical role in integrating typical colour with other object attributes (object shape and linguistic label), akin to its role in combining non-perceptual semantic representations. In separate experimental sessions, we applied continuous theta-burst stimulation (cTBS) to disrupt the neuronal processing in the left ATL and a control site (the occipital pole). Participants performed an object naming task that probes colour knowledge and elicits a reliable colour congruency effect, as well as a control numerical task that also elicit cognitive congruency effect but involves no conceptual integration. ATL stimulation abolished the colour congruency effect, but had no effect on the control task. In contrast, both the colour congruency and control congruency effects were unaffected by stimulation at the control occipital site. Our findings suggest that object colour knowledge requires ATL to implement neural computations of establishing links between typical colours and other object attributes.

53.436 **The color "fruit": Object memories defined by color** David Lewis[1,2](david.lewis@unsw.edu.au), Sieu Khuu[1], Joel Pearson[2]; [1]Optometry & Vision Science, the University of New South Wales, [2]Psychology, the University of New South Wales

Most fruits and other highly color-diagnostic objects have color as a central aspect of their identity, which can facilitate their detection and visual recognition. It has been theorized that there may be a large amount of overlap between the neural representations of these objects and areas involved in color perception. In accordance with this theory we sought to determine if the recognition of highly color diagnostic fruit objects could be facilitated by the visual presentation of their known color associates. In two experiments we show that color associate priming is possible, but contingent upon multiple factors. Color priming was found to be maximally effective for the most highly color diagnostic fruits, when shape information was made ambiguous through the removal of high spatial-frequencies, and when determination of the object's specific identity, not merely its category, was required. These data illustrate the importance of color for determining the identity of certain objects, and support the theory that object knowledge involves sensory specific systems.

53.437 **The contribution of color to detect edges in natural scenes** Thorsten Hansen[1](Thorsten.Hansen@psychol.uni-giessen.de), Karl Gegenfurtner[1]; [1]General Psychology, Justus Liebig University Giessen

Introduction: In a statistical analysis of over 700 natural scenes we found that chromatic edge contrast is statistically independent of achromatic edge contrast and thus is an independent source of information that can be linearly combined with other cues for the proper segmentation of objects (Hansen and Gegenfurtner, 2009, Visual Neuroscience, 26, 35–49). Here we investigated to what degree humans use this information. Methods: We used four freely available data sets of human marked edges (ANID, BSD100, BSD300, SOD). We converted the images to DKL to separate chromatic from achromatic information in a physiologically meaningful way. Edges were detected in the three planes of the DKL color space and compared to human-labeled edges using ROC analysis for a threshold-independent evaluation. Performance was quantified by the difference of the area under the ROC curves. Results were highly consistent across all data sets. The average improvement using chromatic edges in addition to achromatic edges was about 3% on average but reached up to 11% for some images. Performance dropped to about 2% if only a single additional chromatic plane was used. This small benefit matches the performance of dichromats in psychophysical experiments. Interestingly, almost the same benefit of chromatic information (2.5%) occurred for human-marked edges in gray-scale images. Observers probably use high-level knowledge to correctly mark edges even in the absence of achromatic contrast. Summary The advantage of the additional chromatic channels was small on average (about 3%) but reached up to 11% for some images. Overall, color was advantageous for about 90% out of the images. Conclusion: We interpret our results such that edge detection benefits on average from chromatic information, and that this benefit can be very high in some cases.

Color and light: Mechanisms and models

Tuesday, May 14, 8:30 am - 12:30 pm

Poster Session, Orchid Ballroom

53.438 **Opposed interaction of rods and long-wavelength-sensitive cones under mesopic lighting conditions** Florian Bayer[1](Florian.Bayer@psychol.uni-giessen.de), David Weiss[1], Karl Gegenfurtner[1]; [1]General and Experimental Psychology, Giessen University

Signals of rods and cones are combined within the retina already. While two retinal pathways of rod-cone interaction have been identified (reviewed by Sun, Pokorny & Smith, JOV 2001b), consequences on perception are not fully understood yet. We have assessed rod-cone interaction with Gaussian blobs flickering at 1 and 10 Hz. Stimuli were presented by an image display device consisting of two filtered LED-projectors whose beam projections were combined by a semitransparent mirror. By careful calibration using a PR-650 radiospectrometer this device allows independent stimulation of rods and short (S)-, middle (M)-, and long (L)-wavelength-sensitive cones within a contrast range of at least ±10%. The flickering Gaussian blobs (σ=0.2°) were presented at 5° eccentricity on a uniformly gray mesopic background at 4.6 cd/sqm. Four dark-adapted trichromats were examined using a 4-AFC task and the method of constant stimuli. In the first experiment thresholds for rods and cones were determined separately. In agreement with previous findings cone thresholds were higher at 10 Hz than thresholds measured at 1 Hz, whereas rod thresholds did not differ between frequencies (Hess & Nordby, J. Physiol. 1986). In the second experiment each cone flicker was interfered with a constant sub-threshold rod flicker. Thresholds of rod influenced M- and S-cones decreased for both frequencies, suggesting a summation of rod and cone signals. L-cones showed an opposing pattern of interaction with rods: thresholds dropped at 10 Hz as well but increased significantly at 1 Hz. So far, in-phase combination of rod and cone flicker has been reported to augment cone sensitivities (Buck. In: Chalupa, Werner, editors. The Visual Neurosciences. MIT; 2004. pp. 863-878). Our results show that this is not mandatory for L-cones at low frequencies.

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53.439 **Color filling-in percepts from an S-cone pattern** Xiaohua Zhuang[1](xzhuang@uic.edu), Dingcai Cao[1]; [1]Dept. of Ophthalmology & Visual Sciences, University of Illinois at Chicago

Along the l axis, color filling-in percepts depend on the spatial arrangement of the l chromaticity (Zhuang and Cao, VSS 2012). This study examined the role of spatial arrangement along s axis and the interaction of the two cardinal axes in color filling-in process. A rectangular outer field (O) and an annulus (A) surrounded a circular inner field (I). The inner/outer fields had varied s chromaticities (s = 0.6, 1.0 or 1.6) and a fixed l chromaticity (l =0.665). The annulus differed from the inner/outer fields in: (1) only s chromaticity or (2) both s and l chromaticities. Observers reported their percepts continuously during a 25-second steady-fixation-viewing period for each trial. When there was no l difference between the annulus and the other two fields, a monotonic arrangement in s chromaticity (I>A>O or O>A>I) increased the likelihood of the annulus being filled in with the inner- or outer-field color (80% of the monotonic vs. 39% of the non-monotonic trials), while decreased the likelihood of the annulus color spreading into the neighboring fields (monotonic 14% vs. non-monotonic 36%). In contrast, when there was an l difference between the annulus and the neighboring fields, color spreading from the annulus to the inner field was the most frequent percept regardless of spatial arrangement of the s chromaticity (monotonic 20% vs. non-monotonic 24%). Finally, the monotonic arrangement in s chromaticity with or without an l difference reduced time-to-filled-in and increased filling-in percept duration. These results indicate that color filling-in along the s axis depends on the spatial arrangement of the s chromaticity and the presence or absence of an l difference, suggesting that the two cardinal axes do not act independently in color filling-in process.

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53.440 **Color mechanisms revealed by measuring detection and discrimination together.** Timothy G. Shepard[1](timmyshepard@gmail.com), Emily A. Swanson[1], Rhea T. Eskew, Jr.[1]; [1]Psychology, Northeastern University

Much research in human color vision focuses on the psychophysical mechanisms required for the detection and discrimination of color. However, there have been conflicting reports of how many such mechanisms exist. Here, we report results of a study in which detection and discrimination were measured under identical conditions. In the detection task, forced-choice detection thresholds for a 1cpd Gabor patch were measured for many test color angles in the ($\Delta L/L$, $\Delta M/M$) plane. In the separate discrimination task, two stimuli at detection threshold (one "standard" color and another test color, the angles of which were varied between runs) were presented in random order, and observers were asked to select the "standard" angle. Test and standard angles were mostly selected from angles near the ends of the detection contour, near where Hansen & Gegenfurtner (2010, J Vis 10: 388) found highly selective masking, which they interpreted as showing multiple, "higher order" color mechanisms. Qualitatively, (i) if both stimuli are detected by the same mechanism, performance should be at chance level (50%); (ii) if the stimuli are always detected by two different mechanisms, discrimination should be as good as detection (82% or higher); however, (iii) if one or both stimuli are detected by multiple mechanisms, performance should be intermediate (55-65%) since, on some trials, only one mechanism will detect a given stimulus, whereas on other trials two or more will. A Bayesian Color Classifier, threshold-level color categorization model, based upon six unipolar detection mechanisms fit to the detection thresholds, was applied to the discrimination data (Eskew et al., 2001 Vision Research 41, 893). The classifier does a good job of describing discrimination, especially given that there are no free parameters in the model. The discrimination results are consistent with a very limited number of detection mechanisms, not with multiple, "higher order" mechanisms.

53.441 **Tilt illusion and aftereffect from invisible flickering chromatic gratings** 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

Human conscious perception cannot resolve fast chromatic alternations, for example, at over 25Hz. Previous studies have shown that the temporal limitation of conscious color perception is primarily cortical rather than precortical processes (Vul & MacLeod, 2006; Jiang, Zhou, & He, 2007). Indeed, conjunctions of orientation and color are cortically represented at frame rates much faster than the color fusion rate (Vul & MacLeod, 2006). Here we investigated whether invisible orientation information from fast chromatic flickers has any functional consequences for spatially adjacent or temporally subsequent visible orientation information. In other words, we tested whether the invisible chromatic grating could induce tilt illusion (Exp. 1) and tilt aftereffect (Exp. 2). In experiment 1, observers judged the orientation of a low contrast chromatic grating presented at fixation, surrounded by 30Hz flickering red/green chromatic gratings tilted 15 degrees from the principle orientations. Result shows that the center chromatic grating presented at principle orientations were perceived to be 1~2 degrees tilted away from the invisible surround orientation. In experiment 2, we measured tilt aftereffect following adaptation to invisible red/green flickering chromatic gratings. A low contrast test grating 15 degrees different from the invisible adapting orientation appeared tilted 1.5~2.5 degrees further away from the adapting orientation. These results suggest that the invisible orientation information from fast flickering chromatic gratings has functional significance both spatially and temporally.

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53.443 **Non-cardinal Mechanism Visual Search Performance Parallels Cardinal Mechanism Performance Across the Retina, but may be Weaker in the Non-isoluminant Planes of Color Space** Karen L. Gunther[1](guntherk@wabash.edu); [1]Psychology Dept., Wabash College

Hansen, Pracejus, & Gegenfurtner (2009) raised an interesting possibility that non-cardinal mechanisms may be a specialization of the fovea. Cardinal colors are colors that best stimulate the retinal neurons: red, green, violet, chartreuse, black, and white. Non-cardinal colors are all other colors, including ones such as orange and turquoise. Hansen et al. found more circular (not elongated) chromatic discrimination ellipses at 50° than at 5°, suggesting fewer underlying mechanisms and thus the lack of non-cardinal mechanisms peripherally. Here I test this hypothesis by performing visual search with cardinal and non-cardinal stimuli (dot/annulus stimuli of 2.5° diameter, 1.25° central dot; 6 dots total; cardinal stimuli consist of, e.g., red/green target amongst violet/chartreuse distractors) at 0, 10, 20, and 30°, in all three planes of color space. The results so far do not support the hypothesis of foveal specialization of non-cardinal mechanisms. In the isoluminant plane, although performance does drop off in the periphery, it does so equally for cardinal and for non-cardinal stimuli. In the red-green/luminance plane and especially in the violet-chartreuse/luminance plane, performance on the non-cardinal visual search (e.g., intense-red/dim-green target amongst intense-green/dim-red distractors) is difficult even in the fovea. However, as performance drops in the periphery, it does so at similar rates for cardinal and for non-cardinal stimuli.

Acknowledgement: none

53.444 **Unperceived patterned chromatic backgrounds induce large shifts in color appearance** Yanyu Zhang[1](zyy_1031@126.com), Fang Fang[1, 2, 3, 4], Yang Sun[1]; [1]Department of Psychology, Peking University, [2]Key Laboratory of Machine Perception (Ministry of Education), Peking University, [3]Peking-Tsinghua Center for Life Sciences, Peking University, [4]IDG/McGovern Institute for Brain Research, Peking University

Patterned chromatic backgrounds can induce larger color shifts than uniform background (Monnier & Shevell, 2003). However, whether large color shifts can be induced by physically presented but perceptually unawared patterned backgrounds remains an open question. RATIONALE: If the color appearance of an object depends on the perceived rather than physical backgrounds, a color shift should not occur when the chromatic-inducing backgrounds are presented but not perceived. Methods: The object was a partial letter 'S' made of horizontal stripes. The chromatic-inducing pattern was composed of interlacing lime and purple horizontal stripes occupying complementary retinal locations. A mirror stereoscope was used for dichoptical stimulus presentation. The experimental conditions were: (1) the purple stripes and the 'S' embedded in the stripes were presented to one eye and the lime stripes to the other eye; (2) the 'S' and the interlacing purple and lime stripes were presented to one eye and a blank to the other eye; (3) the 'S' and the purple stripes were presented to one eye and a blank to the other eye. Observers' tasks were: (a) matching color appearance to the 'S'; (b) reporting the perceived layout of the stimuli. Results: (i) The color shift induced by condition (1) was no less than that induced by condition (2) and was significantly larger than that induced by condition (3); (ii) the purple and lime stripes of condition (1) were perceived to be completely overlapping, rather than interlacing. The results show that even when the interlacing pattern was not perceived, a significant chromatic induction could still occur. These findings suggest that the color appearance of an object depends on the physical presence of the chromatic-inducing backgrounds, but does not necessarily rely on the perceived backgrounds.

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53.445 **Does "Cortical Yellow" Exist?** Kenneth Brecher[1](brecher@bu.edu); [1]Departments of Astronomy and Physics, Boston University

Ever since Selig Hecht (1928) reported that the binocular fusion of red and green led to the percept of what is sometimes called "cortical yellow," the very existence of this phenomenon has been disputed. In his experiment, red light was presented to one eye, green light to the other. Wratten filters and available incandescent lights were employed. Subsequently, Edwin Land and William Hunt (1936) repeated the experiment utilizing polarizing filters. They also reported a positive result: that is, some observers said they saw yellow, rather than experiencing binocular rivalry. To be clear, these authors were not reporting the appearance or "reddish green" – whatever that is. Nonetheless, many authors have denied the existence of this "dichoptic red plus green equals yellow" effect, sometimes arguing that it is not consistent with ideas of color opponency. As part of "Project LITE: Light Inquiry Through Experiments," we have developed a simple binocular viewer that can be used to probe a wide variety of binocular phenomena. It is designed for use with many smart phones and similar devices (iPhone, iPod, android phone, etc.). We have also developed controllable software using HTML5 that runs on all of these devices (found at http://lite.bu.edu). Together, they help the viewer to experience diverse visual effects including: binocular rivalry; stereopis utilizing novel textured forms of random dot stereograms; binocular luster; as well as binocular addition of colors. The software includes an app to help individual observers make the red and green screen colors isoluminent. Here we report results of our red-green binocular color addition experiments utilizing our viewing device and software. Some observers indeed report binocular rivalry as might be expected classically. However, many observers (including the one presenting this report) see yellow or yellowish orange. The significances of these observations for theories of color vision will be discussed.

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53.446 **Colour constancy in real world scenes: 3D shape -material & object knowledge** Annette Werner[1](annette.werner@uni-tuebingen.de), Lara Zebrowski[1], Ismael Kelly-Perez[1]; [1]Institute for Ophthalmic Research, Tuebingen University

We have previously shown that the quality of colour constancy in real scenes is influenced by properties of surface material, namely by the degree of mesostructure. Material mesostructure and appearant roughness are strongly influenced by 3D shape, as is reflexion from non-lambertian surfaces. We asked therefore how these form-material interactions influence colour constancy. We tested colour constancy for different materials (paper, fur, plastic), which were presented as (1) 3D objects of arbitrary forms, (2) well known 3D forms, and (3) flat surfaces. All surfaces / objects extended approximately the same visual angle (15 deg), the flat surfaces were presented at an angle of 60 deg. The samples were mounted on black sample holders (0.30 x 0.15 x 0.20 m) and were presented in the middle of a "real world viewing box" (1.0 x 1.0 x 0.8 m). The box was lined with multicoloured patches made of a variety of materials. Illumination of the scene was provided by a computer controlled, calibrated LCD-projector (Panasonic PT AE 1000E). The observers (n=5) viewed the samples frontally (viewing distance 0.90 m), with their heads fixed. All samples appeared achromatic after 2 min adaptation to the standard illumination (chromaticities of D65). Colour constancy was quantified by an achromatic setting method, after adaptation to one of four test-illuminants (selected from the cardinal axes in an equiluminant plane in colour space). The colour of all surfaces/objects was known, i.e. "white" under standard light. We found a strong influence of 3D shape on colour constancy performance: colour constancy was highest for the known 3D objects, followed by performance for the arbitrary 3D objects, and least for the flat surfaces. We conclude that the interaction between 3D-form and material provides local, object related cues for colour constancy. Object knowledge (object memory) seems to further support these processes.

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53.447 **Stable short-term dynamics of color contrast adaptation** Katherine E. Mussell[1](kmussell@gmail.com), Michael A. Webster[1], Christy S. Violago[1]; [1]Psychology, College of Liberal Arts, University of Nevada, Reno

Adaptation to some stimulus dimensions has been shown to operate over multiple timescales and to reflect distinct adjustments with potentially different patterns of sensitivity change. We tested for long-term and functional changes in adaptation to chromatic contrast, in observers who had not previously been exposed to stimuli of this kind. The observers adapted to a 1 Hz sinusoidal flicker along the L vs. M chromatic axis in a uniform field presented above fixation. Test probes were interleaved with 5-sec adaptation intervals and alternated between 3 levels of +L contrast (corresponding to 0.25x, 0.5x, or 1x the peak adapt contrast). The perceived contrast at each level was tracked over time by adjusting the contrast of a nearby matching field below fixation, and continued throughout a 1-hr adapt session as well as for intervals before and after. Sessions were repeated over multiple days. Changes in perceived contrast were approximated by exponential functions and had relatively short time constants of ~ 50 sec. Both the magnitude and the time course of both the adaptation and recovery remained similar across successive days, and there was no evidence of a carry-over from preceding days. The form of the response changes also remained similar throughout the adapting period and was intermediate to a subtractive or divisive effect. Our results suggest that at least over the one-hour duration and repeated days tested, there is little evidence for a slow component in color contrast adaptation, or of a potential change in the dynamics of the adaptation with successive exposure.

53.448 **Perceptual luminosity threshold on the surround stimulus that simulates luminance-chromaticity distributions in natural scene** Kazuho Fukuda[1], Ai Numata[1], Keiji Uchikawa[1]; [1]Department of Information Processing, Tokyo Institute of Technology

Perceptual luminosity threshold depends on the chromaticity and luminance of surround colors. It is unclear, however, how luminosity threshold is determined by surrounding colors. Theoretically the luminance-chromaticity distribution of surface colors cannot exceed MacAdam's limit; the theoretical maximum gamut of object colors under given illumination. We previously showed that the luminosity threshold function maintains the stable shape resembling MacAdam's limit regardless of surround colors' luminance-chromaticity distribution and hypothesized that the visual system applies this theoretical or empirical limitation to judge luminosity threshold. To investigate this hypothesis, this study measured luminosity threshold function with regard to several conditions of surrounding colors that simulated the luminance-chromaticity distribution in natural scenes. The stimulus consists of a circular test region and surround overlapping colored circles. There were nine conditions of surround color's luminance-chromaticity distributions simulating LMS cone responses evoked by natural objects' spectral reflectance (Brown, 2003) under the black body radiation at 3000, 6500 or 20000K. In this simulation, 180 of Brown's 574 spectral reflection data were selected to create the following three different shapes of luminance-redness distribution under equal energy white illumination; (1) normal shape where the luminance decreases as the redness deviates from achromatic point, (2) V-shape where the luminance increases as the redness deviates from achromatic point, (3) flat shape where the luminance is constant across the redness axis. Observers were instructed to adjust the luminance of test region to perceptual luminosity threshold. The results showed that the luminosity threshold function maintained the constant shape for all conditions as our previous study showed and translated toward the chromaticity of simulated illumination. In conclusion, the constant shape of luminosity threshold function supports our hypothesis and its translation and statistical analysis suggests that the visual system determines the degree of chromatic translation based on surround colors.

53.449 **How do the S-, M- and L-cones contribute to motion luminance assessed using minimum motion?** Christian Herrera[1](cherrer2@uci.edu), Peng Sun[1], Kier Groulx[1], Charles Wright[1], Charles Chubb[1], George Sperling[1]; [1]UC Irvine

Purpose: To measure the relative contribution of short (S-), middle (M-), and long (L-) wavelength sensitive cones to luminance as gauged with a minimum motion task. Methods: For a given achromatic intensity I, an annular, rotary motion display (subtending the central two degrees of visual angle) was used to find colored lights that were equiluminant to I. The motion display was designed so that, in the context of this display and using a high temporal frequency, a given light would yield ambiguous first-order motion if and only if it was equiluminant to I. Each of ten (4 female) observers was tested using lights of 20 different hues saturated to the maximum extent afforded by our monitor and varying in intensity. For each hue, a 1-up-1-down staircase was used to concentrate observations in the neighborhood of the light that was equiluminant to I. Results: For each observer, the 20 lights estimated to be equiluminant to I projected within measurement error to a plane in the space spanned by the (Stockman-Sharpe) S-, M- and L-cone fundamentals. The axis perpendicular to this equiluminant plane was taken to be the motion luminance axis. This motion luminance axis was then expressed as a linear combination of the (normalized) S-, M- and L-cone sensitivity functions. For three of our observers (all male), the S-cone contribution to motion luminance was negative (as reported by Ripamonti et al., 2009 for flicker luminance) but small. However, for the other seven observers, the S-cone contribution to motion luminance was positive. Wide variations were seen across observers in the relative contributions to motion luminance of the S-, M- and L-cones, from (0.1 : 0.01 : 9.8) to (0.2 : 2.3 : 7.3), in the most extreme cases for a particular I, but in all cases the L-cone contribution was dominant.

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53.450 Perceptual consequences of temporal differences in ON and OFF channels Stanley Komban[1](jkomban@sunyopt.edu), Jianzhong Jin[1], Yushi Wang[1], Reza Lashgari[1], Jens Kremkow[1], Jose-Manuel Alonso[1], Qasim Zaidi[1]; [1]Graduate Center for Vission Research SUNY College of Optometry

The time course of visual responses is thought to play a major role in visual processing. For example, X and Y thalamic cells in the cat (M and P cells in the primate) have different temporal properties and are presumed to serve different functions. In contrast to X and Y visual pathways, ON and OFF pathways were originally thought to differ only in contrast polarity. However, using multi-unit recordings from cortical neurons in layer 4 we found that response latency to dark is shorter than light stimuli. Besides latency difference, we also found that ON and OFF responses are biphasic in nature and that the rebounds are stronger in ON than OFF responses. To evaluate the perceptual consequence of a latency difference we presented two square targets as dark/light pairs on either sides of a central fixation spot. 3 observers were instructed to report the location of the target that appeared first and the proportion of correct responses were calculated for different inter-target onset delays. Observers showed consistent temporal advantage for dark targets when presented on a uniform noise background. To measure the effect of rebound on perception, we used a two interval forced choice paradigm to present two successive spatially overlapping targets of like polarity in a randomly chosen interval. 3 observers were asked to report the interval in which they saw a flicker. The inter-target interval to perceive a flicker at 75% threshold performance was significantly lower for dark targets than light targets consistent with the physiological finding. We thus demonstrate using psychophysics, the functional correlates of latency and rebound differences observed in the neural responses to increments and decrements.

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53.451 A novel colour discrimination test suitable for low vision observers Caterina Ripamonti[1](c.ripamonti@ucl.ac.uk), Sarah Kalwarowsky[1], Marko Nardini[1]; [1]UCL Institute of Ophthalmology

Normal colour vision relies on the absorption of light by the short-, medium-, and long-wavelength-sensitive cones. If one or more cone types are absent, or their function is compromised (e.g., diabetic retinopathy, macular degeneration, Leber Congenital Amaurosis), colour vision is affected. Most of the available colour vision tests (with some exceptions, e.g. Simunovic et al., 1998; Arden & Wolf, 2004; Barbur, 2004) can only assess the degree of colour vision in observers with visual acuity above 0.1 (6/60). To measure the residual colour vision retained by observers with low vision, we have developed a new test that consists of circles of random luminance presented on a computer screen. A small sub-set of circles delineate a large 5-degree square that varies in saturation. Using a 2AFC paradigm, observers indicated whether the coloured square appeared on the left- or the right-hand side of the screen. During the test, the chromaticity of the square changed along several directions of the CIE (1976) Luv space. Using a staircase procedure, we measured the minimum saturation required for each observer to discriminate the square from the achromatic background (white point). We found that for adult observers with normal vision, chromatic discrimination thresholds were equally distant from the white point in all directions. More importantly, affected adults and children, who were unable to perform various standardised tests (including the Cambridge Colour Test) due to their low visual acuity, could successfully complete our test. However, their thresholds had overall larger departures from the white point and were better characterised by ellipses with axes of asymmetrical length, with the main axis being parallel to the protan, the deutan or the tritan confusion axes. The test is a promising tool for measuring and monitoring changes in colour vision due to the progression of a disease or its improvement after treatment.

Acknowledgement: Fight for Sight

53.452 Rendering Ishihara color plates on a computer screen using hyperspectral images: will the scores be the same as the traditional paper test? Joao Linhares[1,2](jlinhares@fisica.uminho.pt), Sergio Nascimento[2]; [1]Anglia Ruskin University, Faculty of Science and Technology, CB1 1PT, Cambridge, United Kingdom, [2]Center of Physics, Campus de Gualtar, University of Minho, 4710-057, Braga, Portugal

The use of hyperspectral imaging data to render digital images enables accurate lighting simulations and color accuracies unattainable with more traditional methods of image acquisition and digital rendering. The goal of this work was to use hyperspectral data to test how accurate is the Ishihara test displayed on a calibrated computer monitor. Hyperspectral images of twenty-three plates of the Ishihara test were acquired from 400-720nm in 10nm steps with high spatial resolution. The spectral data of the paper that encircled the colored plates and the lighting spectrum of the light box were also independently measured. These data were used to generate the monitor simulations of the Ishihara plates. 32 color normal subjects did the test using the Ishihara book and the corresponding images on a calibrated monitor screen. The observers' task was the traditional one of reading the numbers printed on the Plates. Their color vision was also assessed using the Heidelberg Anomaloscope. Only one test was performed on each session being the book test the first one and the screen test the second one. In the screen test the plates were presented in randomized order. 25% of the observers made no mistakes on the paper or screen test. 37.5% made one mistake performing better on the screen test. 12.5% made 2 errors performing better on the paper test. 25% had more than 3 errors performing better on the paper test. These results suggest that the use of hyperspectral images and the spectral information of the illumination to render Ishihara color vision can be used to produce an equivalent Ishihara test on a calibrated computer screen.

53.453 Functional Architecture of the Foveal Confluence in Macaque Visual Cortex Brandon Moore[1](brandon.moore@vanderbilt.edu), Ming Chen[2], Haidong Lu[2], Anna Roe[1]; [1]Vanderbilt University, Nashville, TN, [2]Institute of Neuroscience, Shanghai, China

Visual behavior in primates is dominated by moving the eyes (more specifically the fovea) to objects of interest. Representing the most central part of visual space, the fovea is crucial for providing high spatial acuity needed for tasks such as reading, form identification, face recognition, and is key to natural visual attentional behavior. In early visual cortex, cortical representation disproportionately represents the fovea. However, beyond this, surprisingly little is known about its cortical representation (e.g. neurophysiological data comes primarily from extra-foveal cortex). We hypothesize that, given the known specialized functions performed by the fovea, there should be differences in foveal vs extra-foveal cortical organization. This thinking is based on studies which suggest that the unique functional organizations present in V1, V2, and V4 enable different integrative capabilities within those areas, thereby resulting in area-specific functionalities. To examine this hypothesis, we have conducted optical imaging in the region of the foveal confluence in awake and anesthetized macaque monkeys. We predict differences in the organization (either qualitative or quantitative) of ocular dominance, orientation, color, disparity, and motion in foveal vs extra-foveal cortex. We consider the possibility that at the foveal confluence there are no clear borders (i.e. retintopic reversals) between cortical areas and that the foveal confluence is structured as a single specialized cortical region shared by V1, V2, and V4. Also, given the lack of blue cone representation in the foveal retina, we examine whether there is blue color representation in foveal V1, V2, and V4. It may also be possible to address the question of whether V3 extends to the foveal confluence. Thus far, our preliminary data suggest that ocular dominance columns may be less regularly organized and wider in foveal regions of V1 and that there may be a lack of strong representation of blue in the foveal confluence.

Acknowledgement: EY11744

53.454 Neural Sensitivity in the Lateral Geniculate Nucleus (LGN) of Awake, Behaving Monkeys during a Contrast Detection Task: Comparison of Neurometric and Psychometric Functions Yaoguang Jiang[1](yaoguang.jiang@vanderbilt.edu), Dmitry Yampolsky[2], Gopathy Purushothaman[2], Vivien Casagrande[1,2,3]; [1]Psychology, [2]Cell & Developmental Biology, [3]Ophthalmology & Visual Sciences

Electrophysiological recordings in the early visual pathway of mammals revealed great sensitivities in detecting contrast changes at the level of retinal ganglion cells (RGCs) (Enroth-Cugell & Robson 1966, Kaplan & Shapley 1986), the lateral geniculate nucleus (LGN) (Hubel & Wiesel 1961, Shapley et al. 1981, Derrington & Lennie 1984), and the primary visual cortex (V1) (Ohzawa et al. 1985, Sclar et al. 1990). In each of these areas it was concluded that the most sensitive neurons could potentially explain the contrast sensitivity of the subject (see Barlow et al. 1971 for RGC, Kang & Malpeli 2009 for LGN, Tolhurst et al. 1983 and Hawken & Parker 1990 for V1 sensitivity), but the sensitivities of these neurons have not been directly measured while the subject is actively performing a contrast detection task. Additionally it is unclear how (or if) the magno (M) and parvo (P) retinothalamic pathways contribute differently to a contrast detection task in awake

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animals. Applying receiver operating characteristic (ROC) analysis to single LGN neurons recorded from monkeys performing a two-alternative, forced choice (2-AFC) contrast detection task, we derived a neurometric function for each neuron and compared its sensitivity to that of the animal. We found that LGN P and M neurons were consistently less sensitive than the monkey, and the development of their neurometric functions over time reflected the temporal dynamics of the visually driven response of LGN P and M neurons, respectively. By computing choice probability (CP) we characterized the relationship between single neuron responses in the LGN and the behavioral choice of the animal (Britten et al. 1996). We found that both P and M neurons' activities were weakly correlated with the monkey's choice, and the development of their CPs over time cannot be fully explained by the temporal dynamics of their visually driven responses.
Acknowledgement: R01-EY001778, R21-EY019132, P30-EY008126

53.455 **The Retinotopy of a Prosimian (Bush Baby) Pulvinar** Keji Li[1](tomlikeji@gmail.com), Jay Patel[2], Gopathy Purushothaman[2], Roan Marion[3], Vivien Casagrande[1,2,3,4]; [1]Department of Psychology, Vanderbilt University, [2]Cell and Developmental Biology, Vanderbilt University, [3]Cognitive and Integrative Neuroscience Program, Vanderbilt University, [4]Ophthalamology and Visual Science, Vanderbilt University

The pulvinar nucleus in primates has connections with all known visual cortices, yet little is known about its functions. To clarify the functional organization of pulvinar, a few studies have investigated its visuotopic maps in simians using electrophysiological methods. These studies consistently showed two maps, but the organization of these maps were reported to differ between the New and Old World simians. In this study we investigated the visuotopy of the prosimian bush baby (Otolemur garnettii) pulvinar, as prosimians are considered closer to the common ancestors of New and Old World primates. We used single electrode extracellular recording to determine the retinotopy of the lateral (PL) and inferior (PI) subdivisions of the pulvinar and compared the visuotopic maps to bush baby pulvinar chemoarchitecture. Three subdivisions, the lateral central (PIcl), medial central (PIcm) and medial (PIm) inferior pulvinar, were identified in bush baby PI, using myelin, acetylcholinesterase and cytochrome oxidase staining. We found two visuotopic maps which covered PL and PIcl, a dorsal map in dorsal PL and a ventral map in PIcl and ventral PL. Both maps had a lateral upper field representation and a medial lower field representation. Their central vision representations were found on the postero-medial side of the border between the two maps. The global features of the visuotopic maps, including location, orientation of the central-peripheral and upper-lower field axes, appeared similar between bush baby and the Old World macaque monkey but different from the New World cebus monkey. Using reconstructed 3D models of these maps, however, we found details that differed between bush baby and those reported in macaque monkey. These differences included: 1) the first order representation of the dorsal map, 2) the central vision representation as a point and 3) the vertical meridian representation on a curve in bush baby but not in macaque.
Acknowledgement: NIH grants: EY01778 (VAC) and core grants EY008126 & HD15052

Perceptual organization: Neural mechanisms and models

Tuesday, May 14, 8:30 am - 12:30 pm

Poster Session, Vista Ballroom

53.501 **Correlation Analysis for Multidimensional Signal Detection Evaluation and Comparison with Standard Analyses** Leslie Blaha[1](leslie.blaha@wpafb.af.mil), Tamaryn Menneer[2], Michael Wenger[3], Jennifer L. Bittner[4]; [1]711 Human Performance Wing, Air Force Research Laboratory, [2]Psychology, University of Southampton, UK, [3]Psychology, University of Oklahoma, [4]Ball Aerospace

We evaluated tetrachoric and polychoric correlation analyses as candidate techniques for modeling data in studies employing general recognition theory (GRT). GRT is a multidimensional signal detection theory that provides a rigorous framework for distinguishing among perceptual and decisional effects when perceptual dimensions interact, such as in perceptual configurality (e.g., Cornes et al., 2011). The traditional methods for GRT modeling (Townsend & Ashby, 1986; Kadlec & Townsend, 1995; 1999) employ a set of marginal and non-parametric methods to indirectly estimate the configuration of underlying probability models. Within GRT, violations of some model constructs, like perceptual independence, can be represented theoretically as non-zero correlations in the covariance structure for individual stimuli; the marginal methods do not directly estimate these correlations but instead infer them indirectly. We developed four new applications of correlation estimates, marginal and conditional tetrachoric and polychoric correlations, to examine correlations for the multivariate representation of each stimulus and within responses given between stimuli. The novel correlation and standard marginal analyses were applied to simulated data from known GRT configurations to determine the relative frequency of correct and incorrect inferences made by the two types of analyses. The results show that the marginal methods are very conservative with respect to detecting correlations within perceptual distributions (violations of perceptual independence), and those inferences are corroborated by the conditional tetrachoric correlation estimates. Additionally, the marginal correlation estimates are able to detect response correlations that can result from violations of decisional separability and perceptual separability, such as violation through mean shift integrality. Taken together the four new analyses illustrate various patterns of correlations within identification-confusion responses that can augment traditional signal detection analyses. This simulation study suggests ways in which the two approaches may be combined (as sources of converging evidence) to support inferences regarding multidimensional signal detection models.

53.502 **Spontaneous pre-stimulus oscillations predict direction of ambiguous figure-ground assignment** Joseph Brooks[1,2](brooks.jl@gmail.com), Angus Chadwick[3], Vincenzo Romei[4,5], Geraint Rees[2,5]; [1]School of Psychology, University of Kent, [2]Institute of Cognitive Neuroscience, UCL, [3]Neuroinformatics Doctoral Training Centre, University of Edinburgh, [4]Department of Psychology, University of Essex, [5]Wellcome Trust Centre for Neuroimaging, UCL

Multi-stable perception is a phenomenon characterized by spontaneous changes in the appearance of a stimulus despite unchanging visual input. A well-known example of multi-stable perception is Rubin's ambiguous faces/vase stimulus which fluctuates between being seen as two profile faces or as a central vase shape. Previous work has shown that pre-stimulus BOLD activity in face-selective cortex is predictive of which interpretation will be perceived in the subsequent stimulus. Here, we aimed to further characterize the nature of this pre-stimulus neural activity using the high temporal resolution of EEG. On each trial the participants saw exactly the same ambiguous Rubin stimulus with inter-stimulus intervals ranging from 3-15 seconds (Poisson distributed). Trials were separated into those reportedly perceived as faces and those reported as vases. Fixation was monitored with an eyetracker to ensure no fixation differences (and thus no stimulus input differences) between these two sets of trials. As corroboration for participants' subjective reports, we looked at the amplitude of the post-stimulus N170 ERP component. We found that the N170 was significantly larger for trials reported as faces than those reported as vases suggesting the participants' subjective perceptions were, in fact, in line with their reports. To assess pre-stimulus activity, we computed the spectral power across 4-30 Hz in the second leading up to each stimulus. We found that theta and beta oscillations preceding the stimulus were predictive of the reported direction of figure-ground assignment. Lower power was observed for face percepts than vase percepts. These findings specify the nature of spontaneous pre-stimulus activity leading up to figure-ground organization. Furthermore, the results provide parameters (e.g. frequency and precise timing) which can be used to prime or stimulate the brain in future experiments to establish a causal link between pre-stimulus activity and perception.
Acknowledgement: British Academy Postdoctoral Fellowship & Wellcome Trust

53.503 **Role of gamma oscillations in visual awareness.** Yuranny Cabral-Calderin[1, 2](yurany.cabral-calderin@med.uni-goettingen.de), Carsten Schmidt-Samoa[1], Melanie Wilke[1,2]; [1]Department of Cognitive Neurology, University of Goettingen. Robert-Koch-Str. 40 Goettingen, 37075, Germany, [2]German Primate Center, Leibniz Institute for Primate Research. Kellnerweg 4 Goettingen, 37077, Germany

Synchronized alpha/beta (8–30 Hz) and gamma (>30 Hz)-band oscillations in the visual cortex are suggested to be important for visual awareness (Wilke et al,2006; Fries et al,1997; Uhlhaas et al, 2009). In the present study, we used transcranial alternating current stimulation (tACS) in combination with functional MRI to test the causal role of oscillatory activity in visual perception. tACS is thought to entrain endogenous neuronal oscillations in a given frequency range (Stagg & Nitsche, 2011). Twenty-two healthy subjects were reporting their percepts of a "Structure-from-Motion" (SfM) stimulus while receiving tACS. In the SfM paradigm, an ambiguous sphere is perceived to rotate either to the left or to the right, and the direction of rotation switches spontaneously over time. The behavioral results showed that tACS in the higher gamma range (60 Hz) increased the number of perceptual reversals in comparison with the sham condition. In contrast, tACS in the alpha (10 Hz) and beta (16 Hz) frequency ranges did not affect

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perceptual states. In order to evaluate the changes in neural activity as a function of tACS-stimulation, we next combined tACS with fMRI while subjects were reporting their percepts of the SfM stimulus. In agreement with previous SfM studies (Sterzer et al, 2009), the comparison between spontaneous reversals of perceived motion direction and physical replay revealed increased BOLD activity in visual cortex, superior parietal lobe and insular cortex during spontaneous reversals. Most importantly, comparing sham with 60 Hz before the perceptual reversals showed an increase in BOLD signals in visual cortex as well as cingulate and insular cortex. Taken together, our results provide evidence for a causal role of gamma oscillations in perceptual reversals and point to a critical involvement of cingulate and insular cortex in resolving perceptual ambiguity.

53.504 **Determining Decision Rules and Decision Noise in Signal Detection Tasks**

Carlos Cabrera[1](carlos.cabrera@usc.edu), Zhong-Lin Lu[2], Barbara Dosher[3]; [1]Department of Psychology, University of Southern California , [2]Laboratory of Brain Processes (LOBES), Department of Psychology, Ohio State University, [3]Memory, Attention, and Perception (MAP) Lab, Department of Cognitive Sciences, University of California, Irvine

Despite almost a century of evidence implicating the influence of decision noise in perception, the great majority of research in psychophysics literature follows classical Signal Detection Theory in assigning the locus of internal noise exclusively to representational processes (Fernberger, 1920; Tanner and Swets, 1954). Recently, Rosner and Kochanski (2009) demonstrated that a rating task could disambiguate representational and decision noise components when experiments involved at least three stimulus intensities and four response categories. Moreover, Klauer and Kellen (2012) showed that the invocation of decision noise in rating tasks led to ambiguities in identifying subjects' underlying decision rules. Previously, we presented a novel framework that provides full recovery of both representation and decision noise components from classic signal detection rating experiments by using multiple passes of signal embedded in external noise (Cabrera, Lu, & Dosher, 2011). Here, we extend these results to jointly determine subjects' underlying decision rules and decision noise. In a simulation study, we show that a model of the decision rules correctly matched to those adopted by a simulated observer give improved precision, accuracy, and $\chi 2$ fits with increasing trials and passes, and that they outperform mismatched decision rules in every metric. In a subsequent experiment, subjects completed sessions with a restricted number of response categories as well as sessions with an extended number of response categories. For the restricted response structure, none of the decision rules gave significantly better fits compared to a zero decision noise model. For the extended response structure, one decision rule outperformed the others and gave significantly better fits than the null model. Finally, we also show that subjects' internal representations of the stimuli do not significantly differ for different response structures. As the number of response categories increase, subjects' decision noise becomes more prevalent while representational noise remains unchanged.

Acknowledgement: National Institute of Mental Health, MH081018 National Eye Institute, EY017491

53.505 **Asymmetry in lateral connections can account for lateralization of local/global and face processing**

Ben Cipollini[1](bcipolli@ucsd.edu), Garrison Cottrell[2]; [1]Department of Cognitive Science, UC San Diego, [2]Computer Science and Engineering, UC San Diego

Lateralization of function touches the things we think make us most human: language, use of our hands, our emotions, and how we perceive the world through our eyes. Current theory postulates that lateralization of visual function is due to an underlying asymmetry in the processing of spatial frequency information (Ivry & Robertson, 1998). However, computational models either fail to describe specific neural mechanisms leading to this asymmetry (Ivry & Robertson, 1998), or do not account for behavioral data showing lateralization of visual function in adults (Howard and Reggia, 2007). Lateralization of visual function appears only under low stimulus strength, suggesting that the postulated asymmetry in spatial frequency processing is in feedback or lateral connections, rather than feed-forward connections. We focus here on lateral connections, which have been well-characterized anatomically, and implement a simple connectionist model to examine how these connections affect spatial frequency processing. We show that small variations in the spatial spread of these sparse, long-range lateral connections can bias spatial frequency processing towards low spatial frequencies. We show that these small variations can arise during development, from an interaction between changes in visual acuity with a hypothesized asymmetry in the timing of visual development (Hellige, 1993). Finally, we show that the asymmetry due to these connection differences can reproduce lateralization of visual function found in humans for a variety of tasks using local/global stimuli (Sergent, 1982), faces (Young & Bion, 1981), and frequency gratings (Kitterle et al, 1992; Christman 1991). Our model accounts for more data than any previous model of lateralization of visual function, postulates no new neuro-developmental mechanisms, and is consistent with a host of independent data related to the development of horizontal connections (Katz & Callaway, 1994), visual asymmetries (Plaut & Behrmann, 2011), and visual processing at multiple scales (Hopf et al, 2006).

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53.506 **Neuronal integration in visual cortex elevates face category tuning to conscious face perception**

Johannes Fahrenfort[1,2](fahrenfort.work@gmail.com), Tineke Snijders[3,4], Klaartje Heinen[5], Simon van Gaal[1,2,6,7], Steven Scholte[1,2], Victor Lamme[1,2]; [1]Brain and Cognition, Department of Psychology, University of Amsterdam, [2]Cognitive Science Center Amsterdam, University of Amsterdam, [3]Helmholtz Institute, Department of Experimental Psychology, Utrecht University, [4]Rudolf Magnus Institute of Neuroscience, Department of Child and Adolescent Psychiatry, University Medical Centre Utrecht, [5]University College London Institute of Cognitive Neuroscience and Wellcome Trust Centre for Neuroimaging, University College London, [6]Cognitive Neuroimaging Unit, Institut National de la Santé et de la Recherche Médicale, [7]NeuroSpin Center, Commissariat à l'Energie Atomique

The human brain has the extraordinary capability to transform cluttered sensory input into distinct object representations. For example, it is able to rapidly and seemingly without effort detect object categories in complex natural scenes. Surprisingly, category tuning is not sufficient to achieve conscious recognition of objects. So what neural process beyond category extraction might elevate neural representations to the level where objects are consciously perceived? Here we show that visible and invisible faces produce similar category-selective responses in the ventral visual cortex. The pattern of neural activity evoked by visible faces could be used to decode the presence of invisible faces and vice versa. However, only visible faces caused extensive response enhancements and changes in neural oscillatory synchronization, as well as increased functional connectivity between higher and lower visual areas. We conclude that conscious face perception is more tightly linked to neural processes of sustained information integration and binding than to processes accommodating face category tuning.

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53.507 **Neural substrates of perceptual integration during bistable object perception**

Anastasia Flevaris[1](ani.flevaris@gmail.com), Antigona Martinez[1,2], Steven Hillyard[1]; [1]University of California, San Diego, [2]Nathan Kline Institute

Object perception depends not only on physical stimulus properties but also on endogenous, top-down factors that affect the observer's perceptual state. We compared neural activity elicited by varying perceptions of the same physical image – a bistable moving image in which perception spontaneously alternates between dissociated fragments and a single, unified object. A time-frequency analysis of EEG changes associated with the perceptual switch from object to fragment and vice versa revealed a greater decrease in alpha band (8-12Hz) power accompanying the switch to object-percept than to fragment-percept. Recordings of event-related potentials elicited by irrelevant probe flashes superimposed on the image revealed an enhanced positivity in the latency range of the P2 component (~184-212ms) when the probes were contained within the perceived unitary object. The topography of this positivity elicited by probes during object- relative to fragment-perception was distinct from the topography of the P2 elicited by probes during fragment perception, suggesting that neural processing of probes differed as a function of perceptual state. Two source localization algorithms estimated the neural generator of the difference positivity to lie in the lateral occipital cortex (LOC), a region associated with object perception. These data suggest that objects attract attention and modulate the processing of individual elements occurring within their boundaries, perhaps reflecting the perceptual binding of the elements into a unified object. Importantly, these effects were observed when the perceived "object" in this case emerged as a function of the fluctuating perceptual state of the viewer.

53.508 **Population-code representations of natural images across human visual areas**

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Visual information is represented in multiple areas in the human brain. The primary visual cortex (V1) is typically associated with representing low-level image properties of the visual stimuli, whereas higher-level areas encode more abstract information, such as object category. What is not well understood is how the visual information is represented in the intermediate-level visual areas, such as visual areas V2 and V4. Here we used representational similarity analysis (RSA; Kriegeskorte et al. 2008) to characterize population-code representations of natural images across hierarchy of visual areas (for details on the fMRI data, see Kay et al. 2008; Naselaris et al. 2009). We found a gradual change in the representational similarity structure across the visual areas V1, V2, V3, V4 and LO (lateral occipital area). The representations in V3A and V3B were most similar to that in V3 and were more distinct from the representations in V4 and LO. We aim to characterize the visual features that drive these differences in the representations across the hierarchy of visual areas and to relate the results to computational models of visual processing.

53.509 Roles of subcortical processing in Visual Perceptual Learning

Dongho Kim[1](dongho_kim@brown.edu), Li-Hung Chang[1], José Náñez[2], Yuka Sasaki[1], Takeo Watanabe[1]; [1]Cognitive, Linguistic & Psychological Sciences, Brown University, [2]Psychology, Arizona State University West

Some types of Visual Perceptual Learning (VPL) are highly specific for the location of the stimulus in the visual field. For example, performance enhancement after training on the texture discrimination task (TDT, Karni & Sagi, 1991) is observed only at or close to the location in which a task target was trained. A number of human neuroimaging and monkey unit-recording studies have shown that VPL with such location specificity is associated with changes in the local region of the earliest visual area that retinotopically corresponds to the trained target location. Recently, it has been suggested that some subcortical areas code retinal locations. How does the location coding in the subcortical areas relate to the location specificity in VPL? To address this question, 11 young adults were trained on a TDT for 14 daily training sessions. To counterbalance trained visual fields a target was presented in either the upper right quadrant only (N=6) or the upper left quadrant only (N=5) during training. To measure brain activation during the time course of training, subjects were also asked to perform a TDT during the brain activation measurements at 4 different stages; pre-training, and after the 1st, 6th and 14th training sessions. To examine a location specific effect, a target was presented either at the trained location or an untrained location in each trial. As in Karni & Sagi (1991), performance improved only at the trained location. BOLD signal significantly changed from the pre- training scans to post-training scans only in the ipsilateral part of the caudate to the trained retinal location. When the target was presented at an untrained location, BOLD activation did not significantly change in the caudate. These results indicate that part of the caudate changes in association with VPL and may play a role in the location specificity of VPL.

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53.510 Face profiles versus non-face shapes: Does meaning influence border ownership assignment in the visual cortex?

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Single cell recordings from monkey visual cortex show that many neurons, especially in area V2, are selective for border ownership. These neurons are edge selective and have ordinary classical receptive fields, but in addition, their responses are modulated (enhanced or suppressed) depending on the location of a 'figure' relative to the edge in their receptive field. This selectivity is derived from the image context far beyond the classical receptive field. The large context sensitivity might be interpreted as indicating that border ownership assignment involves object memory. To test this hypothesis, we measured neural border ownership selectivity for silhouettes of face profiles and matched control shapes. The hypothesis predicts that face profiles produce stronger border ownership selectivity than the control shapes. As reported (Ko & von der Heydt, Soc. Neurosci. Abstr. 464.11, 2012), recordings did not show this superiority of faces. Here we report results of two behavioral tests with the same stimuli. (1) One monkey was trained in a match to sample shape discrimination task. Discrimination performance (proportion correct minus chance) was 50% higher for the face profiles than for the control shapes (p = 0.015). (2) In another, 'naïve' monkey that had not seen our test shapes before, we examined whether the face profiles would attract attention more often than the control shapes. The task required one second of fixation during which a face and a control shape were presented simultaneously at symmetrical eccentric positions. The monkey occasionally broke fixation after the onset of the stimuli. In these trials, saccades went to the face profile significantly more often than to the control shape (p=0.008). Thus, while face profiles are clearly distinguished behaviorally, recordings fail to show a corresponding influence on border ownership signals. We tentatively conclude that the visual cortex assigns border ownership without recourse to object memory.

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53.511 Cortically-inspired inhibition subtends better contour integration

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Contour detection is a crucial part of early vision and is thought to underlie many visual functions. A broad class of computational models (Li, 1998; Ross et al., 2000; Ben-Shahar & Zucker, 2004) implements contour integration by enhancing edge configurations in the visual field that are consistent with natural image statistics (Geisler et al., 2001). These configurations are also known as the "association field" in psychophysics (Field et al., 1993) or the "co-circularity condition" (Hunt et al., 2011). This mechanism seems consistent with the lateral excitatory connections found between orientation-tuned cells of the primary visual cortex (Bosking et al., 1997). Within this framework, inhibition is often introduced simply as a regulatory mechanism to prevent runaway activity. We argue that the two main forms of inhibition, i.e., subtractive and divisive, have more specific interpretations in the context of a contour detection task. Specifically, subtractive inhibition may implement a winner-take-all mechanism, which suppresses edges not part of contours and reduces false alarms. Divisive inhibition, also known as gain control or normalization (Carandini & Heeger, 2011), may scale the neural activity locally according to the maximally responding edge detector, preventing the suppression of contours by stronger ones, thus reducing misses. Here we implemented a neural network model of lateral connections and dual inhibition in V1, optimizing parameters for optimal contour detection. We evaluated the model on a dataset of natural curve fragments (Guo & Kimia, 2012), used in computer vision to evaluate the performance of a bottom-up algorithm for contour integration. The model is shown to perform better than state-of-the-art computer vision systems, such as Pb (Martin et al., 2004). Our results suggest that the diversity of cortical inhibition is a key element of early vision, as suggested by recent neurophysiological evidence (Lee et al., 2012), and will help to build better artificial vision systems.

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53.512 Interregional connections across early visual areas in contour processing

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It has been shown that many early visual areas are involved in collinear contour processing. However, the interregional coordination that yields coherent structural percepts has not been fully studied, nor is it clear how background clutter may influence these early visual processes. To answer these questions, we used fMRI to measure activity in early visual cortex while subjects (N = 8) performed a contour detection task. In half of trials, a ring of Gabor elements at 2 degrees eccentricity were aligned to create a perceived contour, and on half they were randomly oriented. Presence or absence of background clutter was also manipulated, with clutter absent on half the trials and present on half. Six regions of interest (two ROIs, containing cortex representing either target Gabors or background Gabors, in each of V1, V2 and V3) were predefined using separate target versus background localizer scans. The first analysis used a GLM to estimate the magnitude of the response for each condition in each ROI. When background clutter was absent, responses in V2 target ROIs were slightly suppressed by aligned contours compared with unaligned, while in the presence of background clutter, responses were significantly stronger to aligned contours than unaligned. The effect of clutter on V2 target aligned/unaligned contrast was significant. In addition, a functional connectivity analysis (psychophysiological interactions or PPI) was run using V2 target ROIs as seeds. In the case with background clutter, there was an increase in V1-V2 task-dependent correlations when perceiving aligned versus when perceiving unaligned contours. Without background clutter, however, V2 showed no interaction with V1. Both the average response magnitude and the PPI analysis suggest different mechanisms may support contour processing without or with background distracters. Additionally, V2 may play a major role in coherent structure perception, especially with complex scene organization.

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53.513 **Neural Preference for Vertical Symmetry** Ruosi Wang[1](ruosiwang@fas.harvard.edu), Yaoda Xu[1]; [1]Vision Sciences Laboratory, Psychology Department, Harvard University

Vertically symmetric patterns and designs are ubiquitous in our everyday lives and can be seen in the body plans of animals and the designs of manmade structures. Although both neurophysiological and neuroimaging studies have documented that mirror reversal objects and patterns are represented similarly in higher order visual object processing areas, a selective preference for vertically symmetric objects or patterns has not been directly observed. Cant and Xu (2012) recently showed that object ensemble processing involves anterior-medial ventral visual cortex, overlapping to a great extent with the scene-processing region the parahippocampal place area (PPA). Here we examined whether this ensemble region shows any sensitivity to object ensembles that contain a vertically symmetric organization. We showed observers a series of object ensembles each containing 16 individual objects organized in a four-by-four matrix. Half of the 16 objects had one identity and the other half had a different identity. For example, a display could contain 8 lemons and 8 anchors, or 8 bows and 8 bells. A total of 40 different object identities were used. Critically, in some of the displays, the objects were arranged to have a vertical symmetry, while in other displays, only horizontal or central symmetry was present. We found that PPA exhibited significantly higher responses to vertically symmetric ensemble organizations than to the other types of ensemble organizations. This effect was absent in the lateral occipital complex (LOC), a brain region previously shown to process the shapes of objects. The interaction between brain regions (LOC vs. PPA) and ensemble symmetry (presence vs. absence of vertical symmetry) was significant, with both the left and right hemispheres displaying similar activation patterns. Our results indicate that PPA may have a preference for object ensembles that have a vertically symmetric organization. Further studies will be conducted to verify this finding.

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53.514 **Testing the sampling model of frequency and probability distortion in a visual numerosity task** Hang Zhang[1,2](hang.zhang@nyu.edu), Laurence Maloney[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

People distort probability information in many tasks. The pattern of distortion can be captured by a linear transformation of log odds: $lo(w(p))=\gamma*lo(p)+b$, where $lo(p)=\log(p/(1-p))$. The slope coefficient γ is roughly .6-.7 in decision making (Kahneman & Tversky, 1979, Econometrica) but typically greater than 1 in equivalent motor tasks (Wu, Delgado, Maloney, 2008, PNAS). What determines γ? In Zhang & Maloney (2012, Frontiers in Neuroscience), subjects estimated the relative frequency of black or white dots in a visual display. We found that their γ decreased with the total number of dots, from 0.88 for 200 dots to 0.73 for 600 dots. We developed a sampling model that could quantitatively account for the numerosity effect. The model assumes one single slope $\gamma 0$ for the same individual and attributes the observed different γ's to the binomial variation in sampling from the display. The model predicts γ to be greater than one when sample size (associated with numerosity) is small enough. It further predicts a specific relationship between the maximum and minimum γ of the same individual. Here we reported a new experimental test of the model. Methods: On each trial subjects judged the average relative frequency of black (white) dots in the two displays. Each display, presented for 0.7 second, consisted of randomly scattered black and white dots. Each display was a binomial random sample from a population, where the numerosity (8,12,18,27) and the population relative frequency (0.1,0.2,…,0.9) were varied across trials. Each numerosity condition had 162 trials, randomly mixed. Twelve participated. Results: The predictions of the model were confirmed. (1) The γ decreased with display numerosity, $F(3,33)=20.7, p<.001$. (2) The maximum γ (numerosity 8) was 1.15 (10/12 subjects >1). (3) The observed minimum γ, varying across subjects from 0.66 to 1.23, was indistinguishable from that predicted from the maximum γ, $t(11)=-0.84, p=.42$.

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Scene perception: Spatiotemporal factors

Tuesday, May 14, 8:30 am - 12:30 pm

Poster Session, Vista Ballroom

53.515 **Texture statistics predict human performance on a range of scene-perception tasks** Krista Ehinger[1](kehinger@mit.edu), Ruth Rosenholtz[2,1]; [1]Department of Brain & Cognitive Sciences, Massachusetts Institute of Technology, [2]Computer Science & Artificial Intelligence Laboratory, Massachusetts Institute of Technology

Human beings can perform various scene perception tasks rapidly and with minimal attention. A brief glance is sufficient for people to determine whether or not a scene contains an animal or a vehicle (Thorpe, et al., 1996; VanRullen & Thorpe, 2001), or to identify basic scene categories and properties such as navigability (Oliva & Schyns, 1994; Greene & Oliva, 2009). Recently, Balas et al. (2009) suggested that the information available at a glance might consist of a rich set of local summary statistics and showed that this model predicts performance in crowding tasks. Here we investigate whether the model can also predict performance on "preattentive" scene perception tasks. We compared performance on rapid scene perception tasks to judgments of "mongrel" images, which are created by coercing random noise to have the same local summary statistics as an original image. Our candidate statistics are the statistics of Portilla and Simoncelli (2000). One group of subjects performed a go/no-go task in which they indicated whether an image shown for 20 ms contained an animal (or, in a second experiment, a vehicle). A second group of subjects made the same judgments about mongrel versions of the images. Responses in the two tasks were correlated, confirming recent findings by Crouzet and Serre (2011) that performance in rapid perception tasks can be largely explained by bottom-up feature pooling models. In a third experiment, subjects were shown either photographs of outdoor scenes (from Google Streetview) or mongrel versions of the same scenes. Subjects were asked about various scene properties, including street layout, scene category, geographic location, and presence of buildings, cars, etc. Responses to the images were well correlated with responses to mongrels, suggesting that the texture statistics of the images can explain much of the performance in these scene perception tasks.

53.516 **Summary statistics support spatiotemporal stability.** Jennifer Corbett[1](jennifer.e.corbett@gmail.com), David Melcher[1,2]; [1]Center for Mind/Brain Studies, University of Trento, [2]Department of Cognitive Sciences, University of Trento

The visual system represents overall statistical, not individual properties of sets. It has been suggested that these summary representations evolved as a complimentary strategy to focused attention, circumventing the visual system's capacity limits. We propose that a primary role of global statistical representations is to build and maintain a stable spatiotemporal context. If summary representations are the basis of spatiotemporal stability, then they should occur in multiple spatial reference frames in order to maintain stability over time and across gaze and head shifts. To test this idea, we used mean size, which is an adaptable attribute encoded over a single visual dimension in a qualitatively different manner than the sizes of individual objects. We examined whether mean size was adaptable across retinotopic, spatiotopic, hemispheric, and monocular frames of reference, as well as whether representations of mean size are built in different temporal windows within different spatial reference frames. In three experiments, we adapted observers to patches of small and large sized dots in opposite regions of the display (Left/Right or Top/Bottom), and tested their perceptions of the sizes of single test dots presented in the adapted regions. We observed a negative adaptation aftereffect, such that participants perceived a test dot presented in the area adapted to large dots as being smaller than the same sized dot presented in the region adapted to small dots (and vice versa) in retinotopic and hemispheric, but not spatiotopic, coordinates. This aftereffect also transferred between eyes. Finally, varying the duration of serially presented streams of adapting dots, we found that retinotopic, hemispheric, and binocular representations emerged during different temporal windows. Overall, our results suggest that mean size is represented across multiple spatiotemporal frames of reference, suggesting that such global statistics may play a fundamental role in maintaining perceptual stability.

53.517 **Errors in numerosity estimation arise from slow drive in magnitude-number mapping** Edward Vul[1](edwardvul@gmail.com), Jess Sullivan[1], Dave Barner[1]; [1]Psychology University of California, San Diego

When estimating the number of dots in an array, people misreport the number with some bias and variability that both scale with numerosity. The increasing variance is thought to reflect constant Weber noise on perceptual magnitude representations, while the increasing bias reflects miscalibrated mapping of magnitudes onto explicit numbers. Here we show that response variability in numerical estimation increases more than would be predicted by a constant Weber fraction because most of the variability arises from uncertainty and slow drift in the mapping of magnitudes onto numbers. We presented subjects with 300 trials in which they estimated the number of dots. Each subject had stable idiosyncratic under/over-estimation biases whose magnitude increased with number (subject reliability: r=0.98). Moreover, the coefficient of variation increased with number. These results are well accounted for by variable magnitude-number mapping within each subject. We estimated each subjects' magnitude-number mapping for 10-trial 'blocks' of the experiment. While adjacent blocks have very similar mapping functions (r>0.8), this consistency drops off as a function of the number of intervening blocks. These results indicate that magnitude-number mapping functions drift slowly within individual subjects over the course of the experiment with a shared-variance half-life of over 100 trials (~10 min). In a separate experiment, subjects quickly learned a magnitude-number mapping through trial feedback (thus disrupting their own individual biases and acquiring new biases we teach them). This learning is forgotten over time with roughly the same time-course as the drift within individuals before any learning. Together these results indicate that instead of constant perceptual magnitude noise, most of the variability in numerical estimation tasks arises from uncertain magnitude-number mapping that drifts slowly over time.

53.518 **Disrupting local structure impairs human scene categorization more than disrupting global texture.**
Heeyoung Choo[1](choo.38@osu.edu), Dirk Walther[1]; [1]Department of Psychology, The Ohio State University

People can accurately categorize natural scenes with brief presentations (Potter, 1975). It has been suggested that this efficient processing is mediated by global texture, e.g., orientation and spatial frequency (Oliva & Torralba, 2001). Recent work, however, showed that local structure, e.g., vertex types and angles, can explain human scene categorization (Shen & Walther, 2012). Here, we independently manipulated the availability of global texture or local structure of scenes. In experiment 1, we selectively removed either category-specific amplitude information or phase information of an image by normalizing amplitude or phase across all images. These manipulated images along with intact images were presented to participants briefly (27-80ms, M=43ms) to categorize the images into beaches, city streets, forests, highways, mountains, and offices. Although removal of phase and amplitude both caused a significant decrease in accuracy, removal of phase was significantly more detrimental than removal of amplitude. In addition, error patterns were significantly correlated between the intact and amplitude-removed images, but not between the intact and phase-removed images. In experiment 2, we manipulated the visual features available in line drawings. Specifically, we used intact line drawings of natural scenes, contour-shifted line drawings, in which vertex information was distorted, and rotated line drawings, in which orientation information was distorted. The task was identical to experiment 1, except for using 27ms of presentation for all participants. The results showed not only a higher accuracy for rotated than contour-shifted images, but also a significant correlation in error patterns between intact and rotated images, but not between intact and contour-shifted images. Moreover, error patterns were significantly correlated between phase-removed and contour-shifted as well as between amplitude-removed and rotated images in spite of a large difference in pixel-by-pixel similarity. Our findings together suggest that human scene categorization relies more on local structure than global texture.

53.519 **How Unitary is Rapid Scene Gist Processing? An Individual Differences Approach**
Anne Hillstrom[1](anne.hillstrom@port.ac.uk), Davina Patel[1]; [1]Department of Psychology, University of Portsmouth

Scene gist processing is influenced by individual differences in speed of perceptual processing [Võ and Schneider, 2010, Visual Cognition, 18(2): 171–200]. In literature on individual differences in intelligence, intelligence is sometimes treated as unitary, roughly synonymous with speed of processing, and other times is decomposed into multiple skills. As both spatial and semantic content are supposed to be influential during scene gist processing, the current study explored whether verbal and nonverbal skill differences would independently affect scene gist processing. Sixty-seven university staff and students participated. Timed, short versions of the Alice Heim test (AH5) assessed non-verbal reasoning (based on comparing geometric shapes) and verbal/numerical reasoning (comparing words or numbers). Judgements of whether or not sentences matched pictures and judgments of the relative spatial location of probe objects were carried out on separate sets of photographs. For half the trials in each task, a 250 ms preview of the picture (without sentences or probe objects) preceded the judged picture. Verbal/numerical and non-verbal skills were highly correlated, so partial correlations were used to measure skill to task relationships. The two preview benefits did not correlate significantly with each other. Non-verbal skill correlated significantly with preview benefit in the spatial task, but not with spatial task performance itself, nor with preview benefit or base performance on the sentence task. Verbal/numerical skill did not correlate significantly with anything. Thus, non-verbal skill affects early processing of scenes; verbal/numerical skill as was measured here does not. Future studies should attempt to find a psychometric test that taps into skill underlying recognition of the semantic nature of a scene.

53.520 **Twelve-picture RSVP sequences support feed-forward models of detection at 75 Hz**
Mary C. Potter[1](mpotter@mit.edu), Carl Erick Hagmann[1], Brad Wyble[2]; [1]Massachusetts Institute of Technology, [2]Pennsylvania State University

Potter, Wyble, and McCourt previously reported that viewers show above-chance detection of a picture in a rapid serial visual presentation (RSVP) when they are given a verbal title (e.g., cut-up fruit) just before or immediately after the sequence, even at a duration as short as 13 ms/picture (75 Hz). We took these results as support for a feed-forward model of detection. However, given that there were only six pictures in each sequence, was detection only possible because of the minimal input load or incomplete masking? Here we report the results for twelve-picture sequences. We presented color photographs of a wide variety of scenes at rates of 80, 53, 27, and 13 ms/picture, with no ISI. The target was never the first or the last picture. In one group the target name was presented before the sequence and in the other group, immediately after the sequence. All pictures were new to the participants and none were repeated in the experiment. Comparing hit and false alarm rates, performance in both groups was significantly above chance at all durations. Whether or not the participant reported detection of the target, each target trial was followed by a forced choice test between two pictures, both of which matched the target title but only one of which had been in the sequence. Given correct detection, forced choice was above chance. The finding that both pre- and post-detection are robust with 12-picture sequences gives further support for feed-forward models of high-level perception.

53.521 **Oddness at a glance: Unraveling the time course of typical and atypical scene perception**
Abraham Botros[1](abotros@cs.stanford.edu), Michelle Greene[1], Li Fei-Fei[1]; [1]Computer Science Department, Stanford University

Our ability to quickly recognize the "gist" of a scene is nothing short of remarkable. However, little is known about the content of mental representations built during brief glances. To what extent does scene gist perception rely on prior experience and expectations? In the face of atypical input, is additional processing necessary for recognition? Here, we examined the perceptual time course of both typical and atypical scene stimuli. We used a carefully-selected collection of real-world scene images, consisting of 50 "odd" and 50 "doppelganger" images. "Odd" images contained improbable real-world situations, such as divers signing papers underwater or a wild animal on a couch. "Doppelgangers" were visually similar to their "odd" counterparts except for the root "oddness." We assessed scene perception using a free-response system coupled with variable presentation time. Ten participants viewed odd and doppelganger images at counter-balanced presentation times (20ms, 40ms, 80ms, 150ms, and 500ms, masked); participants were instructed to type descriptions of what they saw in as much detail as possible. Responses were analyzed using a concept tree in an Amazon Mechanical Turk (AMT) interface. AMT workers evaluated the general correctness and detail, the number and specificity of objects and scene details mentioned, and the demonstrated understanding of the oddness in the picture. There was a steady increase in all of the aforementioned factors as presentation time increased. In addition, all of these factors showed poorer performance for odd images compared to doppelgangers. In particular, participants required between 150ms and 500ms to correctly describe odd images. In shorter presentation times, participants had a defined tendency to rationalize impoverished visual input into sensible explanations more akin to normal visual experience. Overall, this implicates the possibility of top-down constraints imposed on early sensory input in order to maximize hypothesis likelihood, especially for atypical real-world scenes.

53.522 **Space-time characteristics of visual input modulations resulting from saccades**
Naghmeh Mostofi[1](nmostofi@bu.edu), Marco Boi[1], Martina Poletti[1], Jonathan D. Victor[3], Michele Rucci[1,2]; [1]Department of Psychology, Boston University, [2]Graduate Program in Neuroscience, Boston University, [3]Department of Neurology and Neuroscience, Weill Cornell Medical College

 See page 3 for Abstract Numbering System

Under natural viewing conditions, eye movements continually modulate the input signals to the retina. Saccades occur 2-3 times per second, and microscopic eye movements are present during the intersaccadic periods of visual fixation. It is critical to characterize the spatiotemporal input resulting from this incessant alternation between large and small eye movements, as this is the input signal to the visual system. In a previous study, we have focused on fixational eye movements (Kuang et al., 2012) and shown that, during viewing of natural scenes, microscopic eye movements carry out a crucial information-processing step: they remove predictable correlations in natural scenes by equalizing the spatial power of the retinal image within the frequency range of ganglion cells' peak sensitivity, a transformation, previously attributed to center-surround receptive field organization. Here, we focus on the temporal modulations resulting from saccades, which strongly affect neural responses at fixation onset. We show that the space-time transformation due to saccades consists of two distinct regimes. Below a critical low spatial frequency, K, saccades amplify spatial frequency; that is, like ocular drift, the amount of temporal power they yield increases with the spatial frequency of the stimulus. Above K, instead, saccadic temporal modulations equally transform all spatial frequencies. The cut-off frequency K depends on the amplitude of saccades, it is smaller with larger saccades. Furthermore, for any saccade there is a critical high spatial frequency (related to its amplitude) above which the temporal modulations resulting from ocular drift contain more power than those given by saccades. These results suggest that saccades and ocular drift contribute to encoding different frequency ranges, with saccades enhancing low spatial frequencies and drift filling in high spatial frequencies. We present the results of psychophysical experiments which support this hypothesis.

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53.523 **Great expectations guide eye movements in real-world scenes**

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Prior research has determined that our expectations of both target appearance and target location guide where we look when searching for an object in a scene. Expectations of location can be further divided according to the amount of visual information available to the observer. Probable locations could initially be predicted based only on the target identity but without any visual information from the scene ("Eyes closed"). Alternatively, expectations might only be generated after perceiving the scene layout or gist ("Eyes open"). The inter-observer consistency of these expectations was compared in three experiments by asking people to guess where a named object would be located by clicking within a picture frame. The results from Experiment 1 confirmed that people were consistent in their guesses when no visual information was given, but that responses became more tightly clustered when a brief preview of the scene was flashed beforehand, even when the target object was absent. In Experiment 2, the duration of the preview had a systematic effect on the consistency of observers' guesses, with a longer preview making it more likely for participants to agree on an appropriate location. In Experiment 3, the eye fixations of new participants searching the same scenes were predictable based on the guesses from Experiments 1 and 2. Moreover, when participants were forced to make a speeded saccade they tended to fixate the location selected by guessers with less visual information. These results provide a simple method for quantifying expectations, their time-course, and their effects on visual exploration.

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53.524 **Do Scenes Facilitate Action Categorization?**

Adam Larson[1](adlarson@ksu.edu), Ryan Ringer[1], John Hutson[1], Jared Peterson[1], Tera Walton[1], Conor O'Dea[1], Karen Akao[1], Patrick Strouts[1], Lester Loschky[1]; [1]Kansas State University

Previous work has shown that event representations are constructed in a coarse-to-fine fashion (Larson, Hendry, & Loschky, 2012). Specifically, an event's superordinate scene category was recognized first (Indoor or Outdoor), followed by its basic level scene category (Kitchen or Office), and then its basic level action category (Cooking or Washing). This indicates that event representations begin with understanding the scene category. If this is correct, then it suggests that recognizing the scene's category may facilitate action recognition. Conversely, the surrounding scene image may interfere with processing the action, as suggested by Davenport and Potter (2004), who found that object recognition was better with a blank background than with a scene. Lastly, there may be no effect of the scene background on action recognition, suggesting that the two processes are functionally isolated. Participants categorized actions in one of three image conditions: within 1) their original scene background, 2) a gray background, or 3) on a texture background (Portilla & Simoncelli, 2000) generated from the original image. Scene image processing time was manipulated by varying the target-mask SOA from 24 ms-660 ms (i.e., roughly two fixations). Participants then made a Yes/No response to a valid or invalid action category post-cue. The results showed no difference between the original scene and gray background conditions for SOAs <50 ms, but both were significantly better than the texture background condition. However, for SOAs > 50 ms, the original scene background condition was significantly better than the gray background and texture background conditions. These results indicate that semantic scene information does not facilitate action recognition at the very earliest stages of processing, but does so once gist recognition reaches a threshold (the basic level scene gist inflection point generally around 50 ms SOA). Conversely, unrecognizable visual structure interferes with action categorization for roughly 330 ms.

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53.525 **The influence of scene context on object recognition**

Jaap Munneke[1](Jaap.Munneke@unitn.it), Valentina Brentari[1], Marius V. Peelen[1]; [1]Center for Mind/Brain Sciences (CIMeC) - University of Trento, Italy

Previous work has shown that humans can quickly and accurately recognize objects within briefly presented natural scenes. Multiple theoretical accounts have argued for an important role of scene context adding to this process. Evidence for these accounts comes from studies that found improved recognition of objects that were presented in semantically congruent scenes (e.g., a sandcastle on a beach) relative to semantically incongruent scenes (e.g., a sandcastle on a football field). In the current study, we aimed to discriminate between three scene properties that might account for this congruency effect: 1) low-level visual features, which typically overlap more for congruent than incongruent scene-object pairs; 2) local scene properties that require focused attention to be processed, such as other objects in the scene; and 3) global scene properties, or "scene gist", that are known to be processed without the need for focused attention. Experiment 1 replicated the scene congruency effects of a previous report (Davenport & Potter, 2004). Using a new carefully controlled stimulus set, Experiment 2 showed that the scene congruency effect could not be explained by low-level feature overlap between scenes and target objects. Experiment 3 investigated whether focused attention modulates scene congruency effects. Using a location cueing manipulation, attention was focused either at the target object or at the scene background. Recognition of the target object was better when attention was focused at its location. Importantly, the effect of scene congruency on target object recognition was independent of spatial attention. These results are most consistent with the hypothesis that congruent scene context benefits object recognition through the processing of global scene properties that do not require focused attention.

53.526 **Statistical Separation Of Compressed And Uncompressed Natural Color Images**

Michele Saad[1](michele.saad@gmail.com), Alan Bovik[1], Lawrence Cormack[1]; [1]The University of Texas at Austin

Statistical models of luminance images have been applied to a wide variety of computational visual processing tasks such as quality assessment, image restoration, and perceptual image repair. However, the statistics of chromatic images have been much less extensively studied. We have studied the distribution of the HSV hue channel in natural images. Using a corpus of natural color images, we find a model of the joint hue distribution of neighboring image samples. Using this model, we compare the statistics of natural scenes both to a baseline (spatially random sample pairs) and to the statistics of images distorted by JPEG compression. We show that there is a distinct difference in the hue statistics between the three groups. We then repeat the analysis on the L*a*b* space chroma channels, and find that the difference between the groups is less pronounced in L*a*b* space than in HSV space. By randomly selecting 80% of the natural color images in the database, we formed a dictionary of "words" representative of naturalistic color images. Each word was expressed as the joint histogram of the neighboring pixel hue values. From this dictionary, we obtained a coarser representation of the naturalistic color image signatures by a process of vector quantization. We show that the pristine images in the remaining 20% of the image corpus lie much closer in Euclidean distance to the cluster centers than do the distorted versions (and the separation is highly significant). These results are interesting in their own right, and can also be useful for improving upon computational visual processing tasks such as quality assessment, whereby the larger the distance between a distorted image and the natural color scene dictionary, the larger the expected perceived distortion.

53.527 **Structural, not spectral properties underlie human categorization of natural scenes**

Dirk Walther[1](bernhardt-walther.1@osu.edu), Dandan Shen[2]; [1]Department of Psychology, The Ohio State University, [2]Department of Electrical and Computer Engineering, The Ohio State University

Humans can categorize complex natural scene quickly and accurately. Which properties of scenes enable such an astonishing feat? We have recently found the neural representation of scene categories in the PPA to be compatible for line drawings and photographs of scenes (Walther et al., PNAS 2011). This finding allows us to use line drawings as stand-ins for photographs when investigating scene categorization. We performed a six-alternative forced-choice (6AFC) scene categorization experiment and verified that participants could categorize scenes based on line drawings as well as photographs with presentation times as short as 27ms. To explore the critical scene properties we extracted five sets of properties from the line drawings: contour length, orientation, and curvature, and type and angle of contour junctions. We then categorized natural scenes computationally based on the statistical distributions of these properties. Orientation allowed for the highest categorization accuracy. However, we found that the pattern of categorization errors for curvature, junction type and angle provided the best match with errors made by humans in the 6AFC experiment. Thus, properties of junctions appear to be particularly relevant for the human ability to categorize scenes. We verified this computational prediction in an additional behavioral experiment with manipulated line drawings of scenes, in which the junctions were perturbed while preserving contour length, orientation and curvature. As expected, this manipulation led to a significant decrease in categorization accuracy. Our results indicate that the human ability to categorize complex natural scenes is to a large extent driven by the structure of scenes, which is described by contour junctions. Line orientation, which is tightly linked to the spatial frequency spectrum, is useful for computational scene categorization but does not match human behavior. This finding challenges the popular view that natural scene categorization relies on statistical regularities of the spatial frequency spectrum.

53.528 **Natural scenes as spatial concatenations of multi-size, multi-scale visual features**

Xiaoyuan Zhu[1](XIAZHU@georgiahealth.edu), Zhiyong Yang[1,2,3]; [1]Brain and Behavior Discovery Institute,Georgia Health Sciences University, Augusta, [2]Culver Vision Discovery Institute,Georgia Health Sciences University, Augusta, [3]Department of Ophthalmology, Georgia Health Sciences University

Statistical approaches have become a main framework for understanding natural vision in the last two decades. A major unmet challenge of this framework is to develop a statistical model of natural visual scenes and a key element of such a model is the higher-order structures and their statistics in natural scenes. In this work, we developed a probabilistic model of natural scenes where each scene is a sample of a probability distribution in terms of a set of natural scene structures (NSSs) and their spatial arrangements. In this concept, NSSs are multi-size, multi-scale spatial concatenations of local visual features. To compile NSSs from images of natural scenes, we first sampled a large number of multi-size, multi-scale circular patches arranged in a hexagon configuration. We then performed independent component analysis on the patches and obtained a set of clusters of independent components using the K-means method. Finally, for each scene category, we obtained a set of NSSs by clustering the scene patches. To model spatial concatenations of NSSs in natural scenes, we compiled the adjacent matrix for each NSS and obtained the eigenvalues of the adjacency matrix. We examined the statistics and the information content of NSSs. After selecting a set of informative NSSs for each scene category, we used the occurring frequencies and the spatial information of NSSs as features to classify natural scenes in two widely used datasets. We obtained several results. First, NSSs carry a variety of amount of information of natural scenes, including smooth luminance patterns, textures, and patterns with edges and junctions. Second, high accuracy in scene classification using NSSs as features can be achieved. Third, spatial concatenations of NSSs can encode spatial information in natural scenes. We thus conclude that this model of natural scenes is a plausible candidate for human scene perception.

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53.529 **Prediction of Image Naturalness and Quality**

Anish Mittal[1](mittal.anish@gmail.com), Rajiv Soundararajan[2], Alan Bovik[1]; [1]Center for Perceptual Systems, The University of Texas at Austin, Austin, [2]Qualcomm Research, Bangalore, Karnataka, USA

This work studies connections between image naturalness and perceived image quality. Specifically we define an Image Naturalness Index that quantifies intrinsic naturalness of images using features learned from a representative database of natural images. These features derive from models of early visual processing that lead to statistically regular processed images. We have observed that image distortions disrupt statistical image naturalness and that humans are highly sensitive to these disruptions in distorted images they observe. The naturalness index is derived by selecting patches from natural images, then collecting relevant NSS features from these patches to construct a natural image model. A multivariate Gaussian (MVG) distribution is used to characterize them. The 'naturalness' of an arbitrary test image, whose quality needs to be evaluated is expressed as the distance of the MVG model obtained from natural images to the MVG fit on the set of the same NSS features extracted from the patches of the test image. When applied to distorted images, the index is able to achieve image quality assessment (IQA) performance (in terms of correlation with human subjective judgments) comparable to leading full reference IQA algorithms such the Structural Similarity (SSIM) Index and much better than the Mean Squared Error (MSE) which demonstrates its relevance with respect to perceptual distortion sensitivity. This method is different from prior IQA approaches, all of which required both similar NSS models as well as exposure to both distorted images and human judgments of them, replying instead only on a simple natural scene statistic (NSS) model. Conversely, the Image Naturalness Index performs well when constructed using perceptually relevant NSS features extracted from a corpus of naturalistic, undistorted features, but does not function well when using other types of features (such as SIFT features or edges) or if the features are extracted from distorted images.

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53.530 **The Intrinsic Reference System in Spatial Learning: Evidence from a Contextual Cueing Paradigm**

Shiyi Li[1](virtualsun@hotmail.com), Zhongting Wang[1], Haibo Yang[1], Deli Shen[1], Xuejun Bai[1], Hong-jin Sun[2]; [1]Academy of Psychology and Behavior,Tianjin Normal University, China, [2]Department of Psychology, Neuroscience and Behaviour, McMaster University, Canada

It has been proposed (Mou etal, 2004) that when learning a spatial layout, structure of the environment could be interpreted in terms of an intrinsic reference system. Alignment of viewing perspective with the intrinsic axis in the environment would lead to higher recall accuracies than that in misaligned conditions. Here we demonstrate that intrinsic axis of the scene can benefit in spatial learning even in a task involving implicit learning. We used a contextual cueing paradigm where repeated configurations of random elements induce better search performance than that of novel configurations. We examined search behavior in a computer rendered illustrations of a realistic scene. Participants were presented with an array of chairs randomly positioned on the ground and in their normal upright orientations. Observers were presented with a sequence of trials in which they searched for and identified an arbitrarily located target letter positioned on a chair. Half of the trials in each block were repeated over blocks and, in the other half of the trials, the layouts were randomly generated. We found significant contextual cueing with faster RTs in the repeated condition than in the novel condition as participants learned the relationship between repeated stimuli and target location. For both repeated and novel conditions, we varied the information about intrinsic axis by manipulating the orientation of the individual chairs to be either aligned or misaligned (rotated on the ground plane) with the perspective of the observer. We found that when all chairs were oriented in alignment with the perspective, faster learning (greater reduction of RT over blocks) and a greater contextual curing effect was found compared to a condition where the chairs were oriented 20 degree deviated from the perspective. Our results thus allow us to extend previous findings of the role of intrinsic axis to implicit learning.

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Scene perception: Neural mechanisms

Tuesday, May 14, 8:30 am - 12:30 pm

Poster Session, Vista Ballroom

53.531 **Is perceptual averaging an ability or a reflex?: Electrophysiological evidence for automatic averaging**

Alice R. Albrecht[1](alice.albrecht@yale.edu), Brian Scholl[1], Gregory McCarthy[1]; [1]Department of Psychology, Yale University

To cope with the vast amount of incoming visual information, we not only select regions for further processing (constructing a high-resolution representation of a small amount of input, via attention), but we summarize the visual world along multiple dimensions (constructing a low-resolution representation of a large amount of input). In studies of perceptual averaging, for example, observers are able to quickly and accurately extract the mean size of an array of shapes, or the mean orientation of an array of lines. Despite many impressive demonstrations of perceptual averaging in recent years, it is still unclear what kind of phenomenon this is. In particular, is averaging an ability (something that we can intentionally engage when asked to do so by task instructions) or is it an incidental visual process (something that occurs even without a conscious attempt to do so)? We explored perceptual averaging of orientation without an explicit averaging task, by measuring repetition suppression with EEG. Observers viewed static line segments of varying orientations arrayed in an annulus around fixation. Their only task was to respond to rare displays during which a line segment jiggled momentarily (10% of trials, later excluded from the EEG analyses). On Match displays, the mean orientation was identical to that of the previous display (though the individual line segments always had distinct orientations), whereas on No Match displays, the mean orientation differed. Across several conditions, we observed significant suppression in the EEG waveform to Match displays, compared to No Match displays. This difference occurred within approximately 250 ms of the display onset, and was primarily apparent at relatively posterior electrode sites. These and other results suggest that perceptual averaging is an incidental visual process that the mind engages in even when not explicitly tasked to do so.

53.532 **Two stages in scene gist processing revealed by evaluating summary statistics with single-image ERPs**

Iris Groen[1](i.i.a.groen@uva.nl), Sennay Ghebreab[2], Victor Lamme[1], H. Steven Scholte[1]; [1]Cognitive Neuroscience Group, Department of Psychology, University of Amsterdam, [2]Intelligent Systems Lab, Institute of Informatics, University of Amsterdam

Within a few hundred milliseconds, we transform light falling on our retina into percepts of visual scenes. The computational efficiency of this process may be explained by the presence of a rapid "gist" percept that accompanies detailed feature extraction. It is unclear, however, 1) how gist information, often described using biologically implausible image transformations, is computed by the visual system and 2) when and under what circumstances this information is extracted. We addressed these questions using a novel method that combines computational modeling of visual responses with regression analysis on single-image EEG activity. Subjects judged a specific instance of a gist property, "naturalness", for a large set of natural images. For each scene, we computationally estimated visual responses to local contrast, from which we derived two summary parameters: contrast energy and spatial coherence. Behaviorally, we found that spatial coherence correlated with perceived naturalness, whereas contrast energy correlated with reaction times. We then tested whether these two parameters predicted brain activity over the course of visual processing. In experiment 1, we found that contrast energy and spatial coherence predicted differences between single-image event-related potentials (sERPs) both early (80-150 ms) and later (180-250 ms) in time. In experiment 2, we manipulated task relevance, showing that early correlations with sERP differences persist when an orthogonal task is performed, whereas late correlations are only present when gist categorization is required. These results show that 1) gist information in natural scenes can be approximated by integrating local contrast responses, present in areas like LGN or V1, and 2) this process consists of at least two stages: an early, automatic stage and a later, task-dependent stage. Remarkably, this suggests that information maintained by top-down influences can still be described by summary parameters derived from the stimulus, supporting their relevance for perceptual decision-making about visual gist.

53.533 **The time course of natural scene categorization in human brain: simple line-drawings vs. color photographs**

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Human beings are very quick and efficient at categorizing nature scenes. Recent functional MRI studies found that the neural activation in response to line-drawings was similar to color photographs (e.g., Walter et al., 2011). However, it remains unclear whether the time course of braining activity was similar to the different images. The present study was aimed to investigate how the nature scene categorization of line-drawings and color photographs was reflected in event-related potentials (ERPs). Color photographs and line-drawings of six natural scene categories (beaches, city streets, forests, highways, mountains and offices) were adopted as stimuli, which were first used by Walter et al. (2011). All the images were resized to a resolution of 320 * 240 pixels. Each of them was flashed for 13 ms, and then followed by 100 ms of mask stimuli and 500 ms of a blank. The stimulus onset asynchrony (SOA) between the image and the mask was 13, 26, 40 or 213 ms. On each trial, participants were asked to report the scene category by pressing a key after the blank. Each participant was tested for 10 blocks of 96 trials. ERPs were recorded during the experiment. The behavioral results showed that the accuracy was higher for line-drawings than color photographs when SOA was 13 ms, but was lower when SOA was greater than 13 ms. Importantly, the ERP results revealed that a more negative N170 in occipital electrodes and a more positive P2 in frontocentral electrodes were elicited by incorrect than correct categorization of color photographs, whereas a more positive P1 in occipital electrodes and a more negative N2 in frontocentral electrodes were led to by incorrect than correct categorization of line-drawings. These findings help to understand the role of color in rapid scene categorization and how human brain categorizes different visual stimuli.

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53.534 **Human visual areas invariant to eye movements during natural vision**

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During natural vision humans perceive a stable visual world even though they make frequent, rapid eye movements. For this reason, it is believed that the human visual system must contain representations of the visual world that are invariant to eye movements. To investigate this issue we used functional magnetic resonance imaging (fMRI) to record blood-oxygen level dependent (BOLD) signals evoked by natural movies from 5 human subjects under two conditions. In the first condition subjects were required to fixate steadily. In the second condition subjects were allowed to freely make voluntary eye movements. Identical natural movie stimuli were presented in both conditions and were repeated multiple times. If a brain area is invariant to eye movements, then responses during fixation will be similar to those observed during free viewing. If a brain area is sensitive to eye movements, then responses will be different between two conditions. The overall similarity between responses in the two conditions will also be limited by the amount of non-visual response modulation (i.e., signal-to-noise ratio). To identify areas that are invariant to eye movements, for each cortical voxel we first calculated response similarity across repeats within the fixation condition. Next we calculated response similarity across repeats but between the fixation and free viewing conditions. The ratio of these measures reveals which brain areas are invariant to eye movements. We found that voxels located in early visual areas such as V1, V2 and V3 are strongly affected by eye movements. In contrast, voxels in ventral temporal areas including fusiform face area (FFA) and extrastriate body area (EBA) are only weakly affected by eye movements. These results suggest that the ventral temporal visual areas contain a stable representation of the visual world that is invariant to eye movements made during natural vision.

Acknowledgement: NIH

53.535 **Outside looking in: Searching for abstract representations of "place" in scene-selective cortex.**

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Much effort has been focused on understanding how scenes and landmarks are represented in the brain. However, a landmark or scene always has a set appearance; are there brain regions that also represent the more abstract idea of the "place" represented by a landmark or scene? Here we use two completely different visual stimuli that indicate the same place–images of the inside and outside of a building—to see if we can elicit a common code corresponding to that place. Students at the University of Pennsylvania were scanned with fMRI while they viewed photographs of the interiors and exteriors of ten familiar landmarks from the Penn campus. 22 interior views and 22 exterior views were shown for each landmark and no picture was repeated during the course of the experiment. Using multi-voxel pattern analysis, we were able to decode the identity of landmarks from their exteriors based on activity in scene-responsive regions, including parahippocampal place area (PPA) and retrosplenial complex (RSC), replicating previous results from our lab (Morgan et al., 2011). In addition, preliminary results suggest that RSC may contain sufficient information to decode the identity of a landmark's exterior from images of its interior, and vice versa. This generalization across building interiors and exteriors suggests the existence of more abstract coding of place identity within RSC, conveying information that both interior and exterior views indicate the same 'place.' Such a representation might provide a mechanism for linking building exteriors to the spaces that lie within.

Acknowledgement: NSF Spatial Intelligence and Learning Center

53.536 Neural representations of object identity and layout are not separable during scene processing

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Object identity and layout are two essential features of a scene representation. Yet, how these two features interact during scene representation and whether they can be represented independently of each other are not fully understood. Using the fMRI adaptation paradigm, here we examined how attention to object identity and layout would impact scene representation in three key brain regions involved in scene representation, namely, the parahippocampal place area (PPA), the retrosplenial complex (RSC), and the transverse occipital sulcus (TOS). We showed observers in each trial a sequential presentation of two scene images. Compared to the first image, the second image could either be identical, containing only object layout or identity changes, or containing both types of changes. Observers were asked to attend to object identities and ignore layout, or vice versa, and detect changes in the attended feature in the second image while ignoring changes in the unattended feature. In both PPA and TOS, we observed a significant release from adaptation when either or both features changed, regardless of which feature was attended. Responses in RSC followed a similar pattern although none of the effects reached significance. Additionally, responses in both PPA and TOS increased when the ignored feature changed but the attended feature did not, likely due to a prolonged processing required to inhibit a potentially erroneous response. Comparison between brain regions revealed that TOS showed greater modulation to layout changes than did PPA, consistent with an earlier finding we obtained. These results indicate that neural representations of object identity and layout may not be separable during scene processing, and that TOS likely plays a significant role in layout representation.

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53.537 The anterior parahippocampal cortex processes contextual incongruence in a scene

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Introduction: Through visual experience, objects are encoded in association with particular contexts, and these associations probably help the rapid categorization of objects presented in natural scenes since categorization is impaired when objects are seen in incongruent vs. congruent contexts (Joubert et al. 2008). In the visual ventral pathway, the anterior part of the parahippocampal cortex (PHC) may process the relationship between objects and their context (Aminoff et al. 2007, Goh et al. 2004). Correlations between fMRI activity in anterior PHC and object categorization impairment due to contextual incongruence were investigated in the present study. Methods: Young (n=14 age range 20-30) and old subjects (n=17, age >60) were scanned using fMRI, while performing a 2-button rapid object (animal vs furniture) categorization task. Animal- or furniture-objects were embedded in congruent or incongruent contexts and were briefly presented (100ms). An ROI in the anterior PHC was defined as a 10-mm radius sphere around coordinates previously reported (Goh et al. 2004). Results: As previously shown, object categorization was less accurate (-4.4%, $p<0.0002$) and slower (+12ms, $p<0.00001$) in incongruent vs. congruent contexts. This impairment was greater in old (-6.3%, +17ms) than in young (-2.1%, +7ms) subjects. An increase of activity due to incongruence was observed bilaterally in the anterior PHC. The large spread of behavioral impairment values allowed for optimal assessment of correlation between behavioral scores and cerebral activity. A significant correlation was seen between the increase of anterior PHC activity and global categorization impairment ($p<0.05$) mainly explained by the RT increase ($p<0.02$). Conclusion: Our results reinforce the role of the anterior PHC in processing contextual associations between objects and scenes. Incongruent associations may require additional neural processing relative to congruent ones (previously encoded through experience). Performance impairment in object processing due to contextual incongruence may be specifically related with additional processing in anterior PHC.

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Tuesday AM

53.538 Investigating the spatial precision of cortical feedback using fMRI

Lucy S. Petro[1](lucyp@psy.gla.ac.uk), Fraser W. Smith[1], Victoria Shellia[1], Lars Muckli[1]; [1]Centre for Cognitive Neuroimaging, Institute of Neuroscience and Psychology, University of Glasgow

The spatial precision of cortical feedback to V1 was explored using functional magnetic resonance imaging. Feedback may be local, predicting the image point by point or global, predicting the gist. Images were presented to 12 subjects with the lower right quadrant occluded (Smith & Muckli 2010) and at three different spatially-shifted versions (0/2/8 degrees). Multivoxel patterns were extracted from the non-stimulated cortex (i.e. receiving feedback) and entered into a classifier analysis. We first classified between two images presented at the same level of spatial shift, e.g. between image 1 and image 2 both presented at 0 degrees, and secondly cross-classified between images presented at different degrees of spatial shift e.g. training the classifier on images presented at 0 degrees and testing on images presented at 2 degrees. The first analysis revealed that the region of V1 representing the occluded quarter-field carries information that can discriminate surrounding context, as we were able to classify at 76% ($p = 0.0001$), 68% ($p = 0.0060$) and 86% ($p = 0.0001$) between two different images presented at 0 degrees, 2 degrees and 8 degrees respectively (chance equals 50%). The second analysis revealed that the first analysis holds true only to a certain limit of spatial shift. The "occluded" portion of V1 was able to discriminate the surrounding visual context up to 2 degrees, as we were able to cross-classify images at 0 and 2 degrees (64%, $p = 0.0177$), but not at 0 degrees to 8 degrees (53%, $p = 0.1883$), or 2 degrees to 8 degrees (52%, $p = 0.3190$). Cross-classification performance dropped to chance level once the spatial shifts became too large. This relatively high level of precision is somewhat surprising given that anatomically feedback projections fan out, and may indicate a precise interaction between lateral connections and feedback projections.

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53.539 fMRI repetition suppression for scenes in PPA depends on identical feature representation

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Previous functional Magnetic Resonance Imaging (fMRI) research using multi-voxel pattern analysis (MVPA) has identified the parahippocampal place area (PPA) as a brain region responsible for discriminating natural scene categories and determined that color photographs (which contain color, texture, and structure) and contour line drawings (which contain just structure) yield equivalent category-specific patterns of activation in PPA (Walther et al., 2009; 2011). While these findings suggest PPA primarily uses structural information to represent scene category, no research has used line drawings to investigate the role of structural information in the formation of neural representations for individual scenes within a category. In this study, we seek to explore neural representations for scenes by investigating the representational similarity of individual color photographs and line drawings depicting natural scenes in PPA. We used an event-related fMRI design to measure repetition suppression between pairs of color photographs and line drawings. In two pure conditions, the same color photograph or the same line drawing was shown for both presentations. In two mixed conditions, either a color photograph or line drawing was presented first while an image from the opposing image modality depicting the same scene was presented second. Results show robust repetition suppression is only present in PPA for pure pairs, indicating representational differences between individual color photographs and line drawings depicting the same scenes. While MVPA evidence indicates that the structure of a scene is sufficient for PPA to encode scene category, the current study provides evidence that PPA encodes an array of information from individual scenes, including color, texture, and structure. This research expands scientific understanding of the neural processes involved with perception of complex environments by identifying which dimensions of information are included in neural representations of individual scenes.

53.540 Investigating the spatial frequency content of cortical feedback using fMRI

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One aim in contemporary neuroscience is to understand the information processing in cortical feedback to early visual areas, such as its spatial frequency content. It has been shown that V1 can generalise between photographs filtered at different spatial frequencies, and even between line drawings and complete natural scenes (Walther et al., 2011). However, it remains unknown how feedback to V1 generalises between spatial frequencies, i.e. when V1 receives no feedforward scene information. Using functional magnetic resonance imaging, we identified regions of V1 responding to a white occluder presented over the lower right quadrant of spatial-frequency filtered versions of centrally-presented natural scenes. Activation patterns from this "non-stimulated" (and thus feedback-receiving) region of V1 were entered into a multivariate pattern classification analysis (Smith & Muckli, 2010). In the control condition, subjects were shown the scene in the lower right quadrant (henceforth the 'feedforward' condition). We performed two analyses, firstly in both feedforward and feedback conditions, we classified between two different images presented at either high (HSF) or low spatial frequencies (LSF). Secondly, again in both feedforward and feedback conditions, we cross-classified across spatial frequencies i.e. training the classifier on low-spatial frequency images and testing on high-spatial frequency images, and vice versa. The first analysis revealed the "non-stimulated" region of V1 responding to the occluder carries complex information that can discern the surrounding context, as we were able to classify above chance between the two HSF and two LSF scenes, although as expected not as accurately as in the feedforward condition. We were also able to cross-classify in the feedforward condition. However, the missing cross-classification of feedback indicates a lack of generalisation from high to low spatial frequencies, at least in the parameter space measured so far.

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53.541 **Convergence of object and scene layout information in parahippocampal place area** Drew Linsley[1](linsleyd@bc.edu), Sean MacEvoy[1]; [1]Department of Psychology, Boston College

Behavioral data suggest that scene recognition draws heavily upon analysis of global scene properties, such as three-dimensional layout (Greene & Oliva, 2009). At the same time, scene recognition is strongly influenced by the kinds of objects scenes contain (Davenport & Potter, 2004; Joubert et al., 2007; MacEvoy and Epstein 2011). It is unclear how information from object- and global property-based routes to scene recognition combine to generate unitary judgments of scene identity. Recently, we have demonstrated that these routes converge at least partially at a perceptual level, with the presence of diagnostic objects in scenes influencing the encoded values of scenes' global properties (Linsley and MacEvoy, VSS 2012). In the present study, we used event-related fMRI to understand where in the visual system this convergence occurs. In a preliminary phase, a web-based survey was used to rank 500 exemplars of bathrooms on the basis of "spaciousness", a perceptual quantity linked to scene layout parameters. Participants in the fMRI phase viewed briefly-presented exemplars of "average" bathrooms from the middle quintile of spaciousness rankings and "extreme" exemplars from the top and bottom quintiles; the latter were shown both intact and with diagnostic objects masked. Similar to Kravitz et al. (2011), multi-voxel activity patterns evoked in the parahippocampal place area (PPA) by intact bathrooms of extreme spaciousness differed more from each other than from average bathrooms. In parallel with our previous behavioral results showing that the presence of objects in scenes tends to drive encoded spatial properties towards those of the category average, PPA patterns evoked by extreme bathrooms differed significantly more from those evoked by average bathrooms when their objects were masked versus when they were intact. These results provide evidence for convergence of object and global properties information in the neural representations of scenes in the PPA.

53.542 **Frontal Contributions to Natural Scene Processing** Manoj Kumar[1,2](mkumar9@illinois.edu), Fei-Fei Li[3], Diane Beck[2,4]; [1]Neuroscience Program, University of Illinois , [2]Beckman Institute, University of Illinois, [3]Department of Computer Science, Stanford University, [4]Department of Psychology, University of Illinois

Humans are very efficient at categorizing natural scenes. In addition to fast visual processing, such categorization implies contact with stored representations in the brain. Accordingly, we were able to decode natural scene category from both visual areas and regions in the frontal lobe (Walther et al., 2009). Moreover, we've seen better detection and decoding of good exemplars of scenes than bad, suggesting an influence of past experience. Here we explored the relationship between semantics and scene decoding. Specifically, we asked if scenes (for eg. Picture of a beach) and related words (for eg. 'Beach') share common representations in the brain. In an fMRI experiment, subjects passively viewed blocks of either Words or Pictures of scenes, for four different categories: beaches, cities, highways and mountains. A whole brain searchlight, using multi-voxel pattern analysis, was performed on the fMRI data. In keeping with our earlier results, we were able to decode scene category from pictures in occipitotemporal cortex, and the inferior frontal/precentral gyrus. To determine whether the words and pictures share similar representations we trained a classifier on one condition (e.g. word stimuli) and then tested it on the other condition (e.g. picture stimuli). One common area in the precuneus showed weak transfer from pictures to words. This area has previously been associated with imagery, suggesting the successful cross-decoding was visual rather than semantic in nature.

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53.543 **Spatial size defined by different boundary cues** Katrina Ferrara[1](ferrara@cogsci.jhu.edu), Soojin Park[1]; [1]Department of Cognitive Science, Johns Hopkins University

A fundamental challenge in natural scene perception is the selection of reliable visual features to guide our daily navigation. Developmental and animal researchers have found that only certain cues facilitate this process. For example, 4-yr-olds reorient in accord with the geometry of a layout defined by walls only 30 cm high, but fail to do so when the walls are replaced by tape on the floor (Lee & Spelke, 2008). These studies suggest that three-dimensional surfaces serve as informative cues to define a functional space. The present research tests the relationship between different boundary cues and representation of the size of space. We used artificially-created indoor scenes that varied along 1) size of space (Small, Medium and Large), and 2) boundary cue (Wall, Curb and Line). Specifically, the boundary was defined by walls (Wall), vertical structure that was ~4 inches high (Curb), or flat lines on the floor (Line). Participants (N=4) viewed these scenes in blocks of eight seconds while performing a repetition task. We measured multivoxel pattern activity across scene-selective regions: parahippocampal place area (PPA), restrosplenial cortex (RSC), and transverse occipital sulcus (TOS). Using a linear classifier, we found a marginally significant classification in PPA, RSC and TOS (all ps <.1) for the different sizes, but not in LOC and FFA. Interestingly, these scene-selective ROIs did not show classification of the boundary cues. To test whether the extension of three-dimensional surface is important for defining the size of space, we compared the size classification for scenes defined by the Line to scenes defined by the Curb. RSC showed a significant classification for the size of space when defined by the Curb, but not when defined by the Line. These results are consistent with previous findings that show specificity for size of space property in RSC (Park et al., 2011).

53.544 **Using V1-Based Models to Detect Changes in Natural Scenes** Pei Ying Chua[1](cpeiying@dso.org.sg), Kenneth Kwok[1]; [1]DSO National Laboratories, Singapore

We studied the performance of V1-based models in detecting the presence or absence of targets in natural scenes. All models were based on features of the human visual system, and incorporate mechanisms of visual processing such as colour opponency, receptive field tuning, linear and non-linear behaviour, and response pooling. They compare a baseline image and another of the same scene (which may contain a target) to detect if a target is present in the second image. Performance is evaluated by their sensitivity and accuracy in correctly detecting targets. For natural scenes, it is difficult to obtain two images under identical lighting and environmental conditions, and different conditions might lead to false detection of targets. The human visual system has to deal with diurnal changes in the ambient environment and thus human vision models might perform well even with images taken under different conditions. Using models of the visual system, it is possible to investigate the features of human visual processing that enable accurate target detection across a range of ambient conditions. We compared various models' performance in detecting targets using 500 pairs of natural scene images obtained from the publicly available Change Detection Benchmark Dataset (Bourdis, Marraud, & Sahbi, 2011). Performance was measured in terms of sensitivity and accuracy. We found that models that contained response normalisation mechanisms (such as within-field suppression) were more sensitive to targets, while models that replicated eccentricity-dependent contrast sensitivity levels were more accurate in detecting targets. Response normalisation keeps cells within their dynamic ranges which might have contributed towards enhanced sensitivity. Further, models which were tuned to be more sensitive to high spatial frequencies were both more accurate and sensitive, possibly because high spatial frequencies represent the fine details within the image and are thus more likely to contain information about the presence of targets.

Multisensory processing: Cognitive, orienting

Tuesday, May 14, 8:30 am - 12:30 pm
Poster Session, Vista Ballroom

53.545 To Look or to Listen: Evaluating Visual and Auditory Contributions to the Cognitive Restoration Effect

Adam Emfield[1](adam.emfield@gmail.com), Mark Neider[1]; [1]Department of Psychology, University of Central Florida

It has recently been suggested that interacting with different types of real-world environments can influence cognitive performance (Berman, Jonides, & Kaplan, 2008). Specifically, park-like environments appear to have a restorative effect on cognition while busier city-like environments do not. Interestingly, these benefits seem to arise from the visual domain; viewing pictures of these settings produced benefits similar to the environments themselves. These variations may be related to differences in bottom-up attentional demands. In our study, we further explored the cognitive restoration effect by examining (1) whether certain types of visual stimuli that contained water were more likely to induce cognitive improvement and (2) whether other immersion factors, such as environment-related sound, produced additional improvements above visual information alone. We had 202 participants complete a test battery consisting of the Attentional Network Task (ANT), reverse digit span task, and useful field of view (UFOV) task both prior to and following a short intervention. For the intervention, participants were assigned to one of six conditions where they viewed or listened to beach or city pictures, sounds, or a combination of both. In picture conditions, participants viewed 50 images for 7 seconds each; in sound conditions, participants listened to the sound of ocean waves or of New York City for 350 seconds. Contrary to previous research, we found no differential improvement in ANT task performance in any intervention conditions. A similar absence of improvement was observed in UFOV performance. Interestingly, listening to ocean sounds did improve digit span capacity (0.82 digit improvement) while city sounds did not. Overall, our findings suggest that if pictures of certain environments can improve cognitive performance, that improvement is not dependent upon the presence of water. Furthermore, in some cases, auditory information might be better for improving cognitive processing than visual information.

53.546 Unconscious imitation as a metric for crossmodal influences: Visibility of the mouth can enhance alignment to audiovisual speech.

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Human perceivers unconsciously imitate the behavioral characteristics of other humans (e.g., Iacoboni, 2009). Imitated characteristics include body postures (Condon & Ogston, 1967), facial expressions (Hale & Burgoon, 1984), and subtle acoustical characteristics of perceived speech, a phenomenon known as speech alignment (e.g. Goldinger, 1998). Recent evidence shows crossmodal influences on speech alignment (Dias & Rosenblum, 2011, in review; Miller, Sanchez, & Rosenblum, 2010). Our laboratory has shown that integrated audio and visual (lipread) information for a talker's utterance can influence the nuances of perceivers' articulations of that same utterance. Further, these changes in perceivers' articulations seem more sensitive to crossmodal influences than identification responses would reveal. One question raised from these results concerns the facial information that influences alignment to auditory speech. In the current investigation, 10 female undergraduates shadowed (said out-loud) 120 audiovisual words uttered by a talker, presented in auditory noise at a level where all words were easily identifiable (+10 SNR). The shadowed tokens provided either full view of the face, or the face with the mouth area blurred out. Each participant shadowed clear and blurred tokens in block order, counterbalanced between groups. When shadowing blurred stimuli prior to clear stimuli, the degree of speech alignment is enhanced when visibility of the mouth is available, MD = .027, SE = .015, $t(24) = 1.854$, $p < .05$, $r = .354$. No such advantage was found when shadowing clear stimuli prior to shadowing blurred stimuli, MD = -.019, SE = .016, $t(24) = -1.201$, $p = .241$, $r = .238$. The results suggest alignment to auditory speech can be crossmodally enhanced by visibility of the mouth, even when words are easily identifiable. These results support the possibly that in some contexts, inadvertent imitation can provide a more sensitive measure of crossmodal influences than simple identification responses.

53.547 Introducing a Quadristable Auditory Spatial Illusion: Imagining objects moving through space

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Object perception is a multimodal task, involving both sight as well as sound to localize objects. Several visual illusions have made use of multi-stable percepts of object direction and location (Necker, 1832; Kayahara, 2003). Here, we created an auditory correlate of such visual illusions that causes differential interpretations of object direction and location, yet with a constant visual input. This quadristable auditory illusion makes use of back-front confusions to give varying perceptions of an object approaching and retracting from the listener. Observers can perceive the sound as traveling: 1) front to back, 2) back to front, 3) coming from and returning to the front, and 4) coming from and returning to the back. To test this illusion, participants sat in a symmetrical, customized chamber with four speakers positioned on the cardinal axes around them and performed several psychophysics experiments where participants were asked to discriminate between 1) sounds really moving between the speakers and 2) the illusion (which is played equally in the front and back speakers and does not move). When asked to discriminate between real and illusory sounds, observers performed at chance. They localized the illusory sound as all different directional possibilities. When asked to rate their confidence in perceiving a sound cued by directional instructions, they gave equal confidence for the real and illusory sounds (despite the illusion having no direction). When rotated 90 degrees, so that the sounds now traveled between the left and right speakers, observers performed at ceiling. These results show the illusion along the front-back axis is not differentiable from truly moving sounds, and is successful in producing directional percepts. Such quadristable auditory illusions open new opportunities in multimodal science, for studying the perceptual, cognitive and neural representation of objects and space, as well as exploring multi-dimensional perceptual awareness.

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53.548 Visual and Cognitive Predictors of Speech Intelligibility in Noisy Listening Conditions

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Research has demonstrated that visual and auditory cues interact, improving speech intelligibility under noisy listening conditions. For instance, recent findings from our lab demonstrated that simulated cataracts hinder the ability of listeners to utilize visual cues to disambiguate speech. The purpose of this study was to determine which measures of visual, auditory, and cognitive performance predict participants' ability to disambiguate spoken messages in the presence of spoken background noise. We tested 30 young adults with normal visual acuity and hearing sensitivity. Participants completed a battery of visual (monocular/binocular acuity and contrast sensitivity), auditory (left/right ear pure tone thresholds; directed/divided versions of the Dichotic Sentence Identification Test) and cognitive tests (Digit Symbol Substitution Test [DSST], Trail Making Test versions A & B [TMT-A&B]). Speech intelligibility was tested under two conditions: auditory only with no visual input and auditory-visual with normal viewing. Video recordings of Speech in Noise sentences spoken by a talker were presented in the presence of background babble set at a signal-to-noise ratio of -13 dB. Participants wrote what they heard the talker say and the data were scored to calculate speech intelligibility performance based on the percentage of key words correctly reported. Regression analyses show that the best predictors of speech intelligibility were measures of contrast sensitivity and executive functioning, including DSST and TMT-B. The result for contrast sensitivity is consistent with earlier findings suggesting the importance of contrast sensitivity but not acuity in speech intelligibility. The poor predictive power of the auditory measures is likely due to the restricted range of scores in these performance measures since young adults with normal hearing were tested. These results suggest that audiovisual speech integration is dependent on both low-level sensory information and high-level cognitive processes, particularly those associated with executive functioning.

53.549 Neuropsychological evidence for separate shape representations in vision and touch: a study using the Judd variant of the Muller-Lyer illusion.

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The Judd variant of the Muller-Lyer figure consists of a horizontal shaft with an arrowhead at each end; one pointing inward with respect to the shaft (forming the "head" end) and the other pointing outward (forming the "tail"). The arrowhead inducers produce a visual illusion that consists of a displacement of the perceived midpoint towards the "tail" end of the horizontal shaft. The strength of the Muller-Lyer illusion in vision is known to be correlated with the fMRI responses in the lateral occipital area (LO), a region critically involved in representing shape cues in vision. Interestingly, a Judd illusion of similar magnitude is elicited when observers explore the stimulus via touch alone. Importantly, Mancini, Bolognini, Bricolo & Vallar (2011) reported that transcranial magnetic stimulation (TMS) over LO reduced the strength of the Judd illusion both in vision and in touch, an effect they interpreted to reflect the critical role of LO in both visual and haptic shape representation. In contrast to the subtle effects of TMS on cognition and behavior, unilateral damage to area LO in humans produces severe deficits in visual object recognition – a condition known as visual form agnosia. Here, we investigated the magnitude of the haptic Judd illusion in a patient with visual agnosia arising from circumscribed unilateral right hemisphere LO damage. If LO is critical for shape representation via touch (as it is in vision) then unilateral damage to LO should produce a reduction in the magnitude of the haptic Judd illusion. On the contrary, our patient showed a haptic Judd illusion, the magnitude of which was greater via touch that it was in vision. Moreover, despite showing visual object agnosia, his haptic shape recognition was normal. Taken together, our neuropsychological data indicate that LO is not critical for shape recognition via touch.

Acknowledgement: Canadian Institute of Health Research

53.550 **Where I touch is where I see: Visuotactile integration and functional representations of hands and tools.** Hayley Colman[1](h.colman@uq.edu.au), Roger Remington[1], Ada Kritikos[1]; [1]School of Psychology, University of Queensland

There is a dissociation in visuotactile integration depending on the effector that we use (either hands or tools) to complete an action (Maravita, Spence, & Driver, 2003; Maravita, Spence, Kennett, & Driver, 2002). This dissociation relies on the binding of visual inputs at the site of action and tactile inputs arising from the hands (Macaluso & Maravita, 2010). During tool use this manifests as an extension of visuotactile peripersonal space and encompasses the tool tip. Here, we investigated how the interactive properties of hands and tools (action affordances) modulate the integration of visual and tactile sensory inputs. We used foot-pedal and saccadic reaction times (SRTs) in a crossmodal congruency task (CCT) to examine this. In Experiment 1, participants made spatial discriminations of visual stimuli arising from either the grasping (palm) or non-grasping (back) regions of the hand or from hand distant space. Visual stimuli were presented concurrently with tactile stimulation on the sides of the index finger of each hand. Participants were faster to detect targets near the hand compared with those distant from the hand and more so when they arose from the palm-adjacent location. This suggests that crossmodal binding is facilitated in the graspable space of the hand. In Experiment 2 participants were trained with straight stick tools. They then completed the CCT whilst holding a re-configured tool that disambiguated the hemi-space of action (end held by the hand) from the hemi-space of effect (tool-tip) by presenting them on different sides of space. In the other hand they held one of the tools used in training. For the re-configured tool, SRTs were faster to the side of space in which the tool-tip was expected given the straight tools used in training. Taken together, these findings indicate that the actions properties of hands and tools modulate visuotactile integration.

53.551 **Effects of Visual Texture on Food Perception** Katsunori Okajima[1](okajima@ynu.ac.jp), Junya Ueda[1], Charles Spence[2]; [1]Yokohama National University, [2]University of Oxford

Although it is well-known that the color and form of food affect people's taste and flavor perception, relatively little is currently known about the influence of the visual texture of a foodstuff on food perception. We developed an Augmented Reality (AR) system that was capable of changing the texture of food in real time. We conducted a series of experiments designed to investigate how the visual texture and appearance of food influences taste and flavor perception. Participants viewed a video of food (e.g., tomato ketchup) presented on a dish placed in the front of them. The luminance distribution of the food in the dynamic video was continuously and quantitatively modified by tracking specified colors in real-time. We changed the color, the luminance histogram, and/or the visual texture of the food. The participants could see their hand as their spoon dipped into the food from the real time video feed, prior to tasting. The participants reported before and after tasting the food on the expected and perceived flavor. The results demonstrated that people's perception of food can be modulated by changing the luminance histogram of the visual image. In addition, the results revealed high correlations between solidity/liquidity estimations with appearance and tasting, thus providing the first empirical evidence that the visual texture, independent of any change in color, affects the perceived texture of an ecologically valid foodstuff. The effect of visual texture on food texture were highly consistent across participants, whereas the effects of visual texture on flavor perception were not, suggesting that higher-order food attributes may reflect individual experiences that are more complicated than for texture perception (sensory-discriminative response).

53.552 **'When I Move, You (cognitively) Move': action observation and the fusion illusion.** Connor Reid[1](connor.reid@utoronto.ca), Gerome A Manson[1], Luc Tremblay[1], Timothy N Welsh[1]; [1]Faculty of Kinesiology & Physical Education, University of Toronto

In shared environments, one actor's response may serve as an event code for an observer (Sebanz et al., 2003). This activated event code may then be used by the observer to simulate the performance of the actor. What remains to be determined, however, is if this observation-evoked simulation is confined to visual processing or if it extends to the processing of multisensory information. Shams et al. (2000; 2002) reported audio-visual phenomena in which conflicting auditory information biases visual perception. In the fusion illusion, a single flash and two beeps are erroneously perceived as two flashes, and in the fission illusion, two flashes and a single beep are perceived as one flash. Interestingly, Tremblay and Nguyen (2010) demonstrated that participants are more accurate at reporting the number of flashes when stimuli are presented at the portion of a goal-directed movement where limb velocity is highest. Given the proposed link between action and perception, the current experiment was designed to evaluate whether participants' performance on these illusions would benefit from observing a goal-directed movement similar to Tremblay and Nguyen. Participants (n=12) fixated a target on the aiming board and reported the number of perceived flashes after either executing or observing an aiming movement. Audiovisual stimuli were presented at 0ms, 100ms, or 200ms relative to movement onset. Partly consistent with Tremblay and Nguyen, participants were more susceptible to the fusion illusion when the stimuli were presented late (200ms) relative to earlier in the trajectory (100ms). Critically, this pattern emerged in both performance and observation tasks. This finding is consistent with the hypothesis that observers simulate the performance of the actor and, hence, experience comparable alterations in multisensory processing. It is also possible, however, that the modulation of the illusion occurred because the limb displacement on the retina provided contrasting cues.

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53.553 **Cognitive style predicts the perception of visual apparent motion** Lihan Chen[1,2](CLH20000@gmail.com), Xuena Wang[1], Lin Yao[1], Xiaolin Zhou[1,2]; [1]Center for Brain and Cognitive Sciences and Department of Psychology, Peking University, [2]Key Laboratory of Machine Perception (Ministry of Education), Peking University

Cognitive style refers to the characteristic way in which individuals conceptually organize the environment. With Embedded Figure Test, individuals can be categorized as filed-dependent vs. field-independent. Here we investigate to what extent the individual differences in cognitive style could affect the perception of visual apparent motion. We presented participants with two successive frames of a visual Ternus display (Ternus, 1926). Depending on the inter-stimulus interval (ISI) between the two frames, participants could perceive either "element motion" (short ISI) or "group motion"(long ISI). In Experiment 1, the Target display could be flankered by two other Ternus displays at the upper and lower locations. The ISI between the two frames of these distractors could be equal to or longer (260 ms) or shorter (50 ms) than the ISI in the target display. In Experiment 2, the visual Ternus frames were enclosed by four auditory beeps, with the inter-beep interval between the two middle beeps either equal to or longer or shorter than the ISI of the Ternus display. Depending on the time interval between the outer beeps and middle beeps, participants could either group the middle beeps together ("middle pair") or group the middle beeps separately with outer beeps ("end pair"). The percept of the target display was affected by the distractor displays or auditory beeps. In Experiment 1, the "equal" distractors biased the percept to be "group motion" and the "shorter" distractors biased the percept to be "element motion"; importantly, field-dependent group reported more percepts of "element motion" in the "shorter" condition. In Experiment 2, the "end-pair" condition led to more percepts of "group motion" for the field-dependent, but not for the field-independent participants. These findings suggest that cognitive style affects the perception of ambiguous visual apparent motion, possibly mediated by the processing of distracting information.

53.554 **Eye fixations during encoding of familiar and unfamiliar language**
Lauren Mavica[1](lkogelsc@fau.edu), Elan Barenholtz[1], David Lewkowicz[1]; [1]Florida Atlantic University

Previous research has shown that infants viewing speaking faces shift their visual fixation from the speaker's eyes to the speaker's mouth between 4-8 mo. It is theorized that this shift occurs in order to facilitate language learning, based on audiovisual redundancy in the speech signal. In the current study, we asked whether a similar behavioral trend would be present in adults when encoding speech in an unfamiliar language. We presented English-speaking, monolingual adults with videos of a female reciting short sentences in English and in a non-native language (either Spanish or Icelandic), in separate blocks. In order to ensure participants were encoding the sentences, we had them perform a simple task: on each trial, they were presented with video clips of two different (same language) sentences, shown in sequence, followed by an audio-only recording of one of those sentences. Participants had to choose whether the audio-only sentence matched the first or second video. We found that participants gazed significantly longer at the speaker's mouth during the unfamiliar-language blocks compared with the native language blocks. These findings demonstrate that adults encoding speech in an unfamiliar language exhibit gaze patterns that are similar, in some respects, to infants who are first learning their native language—that is, there is enhanced allocation of attention to the mouth region. This suggests that people rely on multisensory redundancy when encoding unfamiliar speech signals.

53.555 **Multisensory Integration in Visual Pattern Recognition: Music Training Matters**
Avi Aizenman[1](aizenman.avi@gmail.com), Jason Gold[2], Robert Sekuler[1]; [1]Volen Center for Complex Systems & Department of Psychology, Brandeis University, Waltham MA , [2]Department of Psychological and Brain Sciences, Indiana University, Bloomington IN

Humans' talent for pattern recognition requires collaboration between perception and memory. Recently, Michalka et al. (2012) showed that a task involving rapid presentation of visual stimuli can activate cortical regions normally implicated in auditory attention. As music training is known to fine tune the human auditory system (Kraus & Chandrasekaran, 2010), we hypothesized that such training might improve performance on rapid temporal tasks, not only for auditory stimuli, but also for visual and multisensory stimuli as well. To test this hypothesis, we adapted a paradigm introduced at VSS 2012 (Aizenman et al., 2012). Subjects received randomly-generated eight-item long sequences of luminances, tones, or both together, all presented at 8Hz. Subjects judged whether or not the second four items in a stimulus sequence were an identical repetition of the first four items presented. Performance was evaluated as values of d'. Four trial types were presented in separate blocks: Auditory alone, Visual alone, AV-congruent (luminance sequences accompanied by auditory tones whose frequencies were cross-modally matched to the luminances), and AV-incongruent (luminance sequences accompanied by randomly generated, incongruent tones). For both types of AV trials, subjects were instructed to base their judgments on the luminances alone, ignoring the tones when deciding whether the luminance sequence repeated. Fifteen subjects with music training (6-15 years) and fifteen subjects with minimal music training (<3 years) were tested. Overall, music-trained subjects outperformed non-music trained subjects ($p<.01$). For both groups, performance was significantly better on AV-congruent trials than on all other trial types. When auditory and visual sequences are in perceptual correspondence, subjects can exploit this correspondence to enhance judgments that are nominally visual. Our results are consistent with the hypothesis that music training improves performance with rapidly presented stimulus sequences, even for visual sequences.

53.556 **Arbitrary sounds facilitate visual search for congruent objects**
L. Jacob Zweig[1](jacob.zweig@gmail.com), Satoru Suzuki[2], Marcia Grabowecky[3]; [1]Department of Psychology, Northwestern University, [2]Department of Psychology and Interdepartmental Neuroscience Program, Northwestern University, [3]Department of Psychology and Interdepartmental Neuroscience Program, Northwestern University

Multisensory correspondences are thought to form through Hebbian-type learning, whereby repeated exposure to coincident auditory and visual signals promotes the formation of auditory-visual associations. Previous research has demonstrated that feature-based multisensory correspondences influence perceptual processing (Iordanescu et al., 2010). For example, when searching for keys among clutter, participants are faster to detect the spatial location of the keys when the characteristic sound of keys jingling is played at the onset of search. It remains unclear, however, whether such facilitation in perceptual processing relies on natural correspondences or whether newly learned associations might similarly facilitate processing. In the present study, we demonstrate that learned arbitrary sounds facilitate visual processing of an associated object, despite the absence of spatial information in the auditory signal. We trained participants to associate two pairs of visual stimuli each with a single arbitrary sound. Visual stimuli consisted of kaleidoscope images that varied in spatial frequency, shape, size, and color. Learning was verified with a two-alternative task in which participants had to correctly match a presented sound to the associated kaleidoscope image. Following training, participants performed a visual search for target kaleidoscopes from one of the previously learned sets with simultaneous presentation of target-congruent or target-incongruent sounds. We demonstrated that a non-spatially informative target-congruent sound speeds visual search to the associated target object. Accuracy did not significantly differ across the two sound congruency conditions and there was no evidence of a speed-accuracy trade-off. These results suggest audiovisual integration may facilitate visual processing and detection by increasing the salience of target objects.

53.557 **The cat and the fiddle: Task difficulty and semantic congruency of multimodal stimuli.**
Bonnie L. Angelone[1](angelone@rowan.edu), Lyle Zanca[1]; [1]Psychology Department, College of Science & Mathematics, Rowan University

Previous research has investigated the effect of semantic consistency and inconsistency in the role of object perception, detection, and identification. There is mixed evidence for a relationship between scene relevancy and object detection (Biederman, Mezzanotte, & Rabinowitz, 1982; Hollingworth, 1998). While this research has utilized visual stimuli alone, other studies have shown facilitation of visual search performance in complex changing arrays with the presentation of an auditory cue that is uninformative and unrelated to the task (Ngo & Spence, 2010; Klapetek, Ngo & Spence, 2012). The current study investigated semantic congruency between auditory and visual stimuli and the effect these stimuli had on attention-based processes in a visual search task under differing levels of task difficulty. Observers viewed an array of six Snodgrass objects (presented in color) accompanied by an auditory stimulus that was either semantically congruent or incongruent with the target in a visual search task. When the task was less attentionally demanding (target category membership was easily determined), there was no difference in search for congruent and incongruent trials. However, when the task required more attentional resources (target category membership was more difficult to determine) visual search was both faster and more accurate for congruent compared to incongruent trials. Having semantically congruent (match) auditory and visual stimuli, compared to semantically incongruent stimuli (mismatch), facilitated performance and speeded reaction time but only when task demands increased. In addition, there was no difference when the visual search task was presented with no sound. This suggests that observers utilize congruent auditory information only when task difficulty is increased.

53.558 **Music facilitates mental rotation performance in women**
Julia Mossbridge[1](j-mossbridge@northwestern.edu), Marcia Grabowecky[1], Satoru Suzuki[1]; [1]Department of Psychology, Northwestern University

Many people listen to music while performing tasks requiring working memory, but it is unclear whether simultaneous music affects working memory performance. To address this question, we used a classic visuospatial working memory task, Shepard's mental rotation. This task requires visuospatial mental manipulation to determine whether two simultaneously presented 3-D objects depicted from different viewpoints are the same object. Participants performed the mental rotation task in two conditions: 1) in silence and 2) while listening to Beethoven's Moonlight Sonata, a calming piece of music. Condition order was counterbalanced across participants (N=40; 20 female). In both conditions, we asked participants to press one key if they thought the objects were the same and another if they thought the objects were different. Speed and accuracy were both emphasized in the instructions. As has been shown previously in silence, women's responses were slower than men's (accuracy was equivalent). In music, women's responses became significantly faster while men's responses became somewhat slower. A gender by condition interaction confirmed the effect (all rotation angles: $F[1,38]=5.728$, $p<0.03$; only angles 140 to 220 degrees: $F[1,38]=13.242$, $p<0.001$). There were no main effects or interactions involving accuracy. Thus, for women, mental rotation performance can be transiently improved with the simple manipulation of playing music. Is the effect due to the calming influence of Moonlight Sonata, or the arousal induced by music? When we used a highly arousing musical piece (Wagner's Ride of the Valkyries), preliminary follow-up results (N=32; 16 female) indicate that although both women and men responded faster in music, women's performance improved in music while men's performance degraded, so that men's advantage in silence

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(in accuracy in this case) disappeared in music. In summary, our results suggest that listening to music improves mental-rotation performance in women likely because women benefit from increased auditory arousal.

Tuesday Afternoon Talks

Perceptual learning: Specificity and transfer

Tuesday, May 14, 2:30 - 4:15 pm
Talk Session, Royal Ballroom 1-3
Moderator: Jun Yun Zhang

54.11, *2:30 pm*

Training of Number Sense Transfers Broadly
Justin Halberda[1](halberda@jhu.edu), Daphne Bavelier[2], Barbara Landau[3], Kerstin Hellgren[4], Lea Forsman[4], Ted Jacques[2], Melissa Libertus[1]; [1]Psychological and Brain Sciences, Johns Hopkins University, [2]Brain and Cognitive Sciences, University of Rochester, [3]Cognitive Science, Johns Hopkins University, [4]Institutionen för klinisk neurovetenskap, Karolinska Institutet

We explore individual differences in the precision of the Approximate Number System (ANS), and the trainability of this key process for apprehending the number of objects in our environment. This system, anchored in the dorsal stream, impacts many of our decisions – from trying to determine the fastest cashier line at the grocery to high-order cognitive tasks such as school arithmetic. The ability to improve its precision through training therefore holds the promise to impact many different aspects of cognition. Here we show that the precision of the ANS is highly plastic, being compromised or enhanced in various populations. In individuals with dorsal stream abnormalities, such as Williams Syndrome or pre-term infants, we find reduced ANS precision. In contrast, in individuals known to have enhanced dorsal stream functions such as action video game players, we find that the precision of the ANS is enhanced (see Supplemental). We then establish that the ANS can be trained and that the benefit of training transfers broadly. Adults trained on action video games exhibit improved performance on tasks related to the ANS including speeded symbolic arithmetic challenges. Children trained with a visually-based number training protocol also showed greater ANS precision as well as transfer to auditory number discrimination (see Supplemental). Our results demonstrate a large plasticity in the precision of the ANS. This system is impacted – for better or for worse – by both genetic and environmental factors. Crucially, its precision can be trained with the induced improvement transferring to untrained modalities and to high-order cognitive tasks. We take the ANS to be a model system of how the more abstract representations of the dorsal stream may be responsive to training and how their precision can affect cognition quite broadly.

Acknowledgement: NICHD

54.12, *2:45 pm*

When numbers and statistics collide: Competition between numerosity perception and statistical learning
Jiaying Zhao[1](jiayingz@princeton.edu), Liat Goldfarb[2], Nicholas B. Turk-Browne[3]; [1]Department of Psychology, Princeton University, [2]Edmond J. Safra Brain Research Center for the Study of Learning Disabilities, University of Haifa, [3]Department of Psychology, Princeton University

The visual system can extract statistical information from a single experience (summary perception) and across multiple experiences (statistical learning). We recently discovered that summary perception and statistical learning cause mutual interference: extracting the average orientation of a set of objects impeded statistical learning about spatial regularities, and the presence of regularities to be learned reduced the accuracy of average orientation estimates (Zhao et al., 2011). Here we extend these findings to the related domain of numerosity perception — our ability to rapidly estimate the number of objects currently visible in the environment. Across three between-subjects experiments, observers were familiarized with arrays of varying numerosity constructed from four spatial pairs and two singles of colored circles. In Experiment 1, we demonstrate that numerosity estimation prevents statistical learning of the color pairs, which was robust after passive viewing and in a control dual task. In Experiment 2, we show that this interference is bidirectional by observing improved numerosity estimation accuracy for arrays that did not contain spatial regularities over time. In Experiment 3, we clarify that reduced numerosity accuracy for arrays with regularities results from learning of the regularities, not the presence of regularities per se. These findings are notable for at least three reasons. First, they replicate the surprising pattern of mutual interference that we observed previously for summary perception of average orientation. Second, these results generalize our previous findings of interference by statistical learning to a different kind of summary statistic, and one that has been studied extensively and is thought to be computed automatically. Third, numerosity perception represents an even stronger test of the theorized overlap between summary perception and statistical learning: Unlike the estimation of average feature values, estimating numerosity does not require representing the identities of objects beyond their mere existence as discrete entities in space.

Acknowledgement: US-Israel BSF 2011315 (to LG & NTB)

54.13, *3:00 pm*

Non-retinotopic, object-centered visual perceptual learning
Mark Vergeer[1,2](mark.vergeer@ppw.kuleuven.be), Izabela Szumska[1], Haluk Öğmen[3], Michael H. Herzog[1]; [1]Laboratory of Psychophysics, Brain Mind Institute, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland , [2]Laboratory of Experimental Psychology, KU Leuven, Belgium, [3]Department of Electrical & Computer Engineering, Center for Neuro-Engineering and Cognitive Science, University of Houston

In perceptual learning, perception improves with practice. Perceptual learning is mainly investigated with retinotopic paradigms. Here, we show evidence for perceptual learning within a non-retinotopic frame of reference. During the training phase, we presented three disks. In the center disk, dots moved upwards with a slight tilt to the left or right. Observers indicated the tilt. Performance improved significantly by 33% on average. Before and after training, we determined performance for various "moving conditions". First, three empty disks were presented at the same location as in the training condition. Then, there was an ISI of 100ms and the disks shifted one disk position to the right (i.e., a Ternus-Pikler display), creating the impression of apparent motion. The same motion as in the training condition was presented either in the left disk, which retinotopically overlapped with the training disk, or in the center disk. The center disk did not overlap with the training disk in retinotopic coordinates but corresponded to it within the object-centered reference frame induced by the Ternus-Pikler motion (the center disk of the first frame maps on the center disk of the second frame). We found that learning transferred only in the latter, non-retinotopic condition. Our results indicate a non-retinotopic, object-centered component to visual perceptual learning. We propose that non-retinotopic learning occurs because both objects and our eyes move constantly leading to retinotopically varying representations. Hence, perceptual learning may best be achieved after spatial invariance is reached.

Acknowledgement: This work was supported by the Pro*Doc project "Basics of visual processing" of the Swiss National Science Foundation (SNF) and in part by award R01 EY018165 from the National Institutes of Health (NIH).

54.14, *3:15 pm*

Speeding up Learning: Action Video Games and Perceptual Learning
Ruyuan Zhang[1](rzhang@bcs.rochester.edu), Shawn Green[2], Zhonglin Lu[3], Daphne Bavelier[1,4]; [1]Brain and Cognitive Sciences and Center for Visual Sciences, University of Rochester, [2]Department of Psychology, University of Wisconsin-Madison, [3]Department of Psychology, The Ohio State University, [4]FPSE, University of Geneva

Playing action video games induces improvements in a variety of perceptual and attentional tasks. Here, we investigated possible mechanisms underlying these improvements. One possibility is that action video game experience conveys upon the users an increase in general visual sensitivity. Such a view predicts that the action video game player (VGP) advantage is not dependent on experience with each new task, but will instead be present on the very first trial. Conversely, action video game experience may result in an increased ability to learn task-relevant statistics. This "learning to learn" view predicts reasonably equivalent performance between groups early on in a perceptual learning paradigm, with the VGP advantage appearing and then increasing through experience with the task. To test these hypotheses, VGPs and non-action video game players (NVGPs) performed a peripheral Gabor orientation identification task in high Gaussian external noise. Consistent with the learning to learn hypothesis VGP and NVGP performance was similar in the earliest trials, but as the task proceeded, VGP performance improved faster than NVGP performance. To further understand the source of this faster learning, two randomly assigned groups of low gamers

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were trained in the essentially the same orientation identification task. The only difference was that in this experiment, the orientation task was embedded within the context of a video game. In one group the game was an action video game, while for the other it was a non-action game. Consistent with the results of the first experiment, perceptual learning was observed to proceed at a faster pace when embedded in an action game. Together, these results indicate that those individuals who regularly play action video games learn faster in new tasks, and that the very act of learning in the context of an action game speeds up learning as compared to other games.

54.15, *3:30 pm*

The time-course of rapid stimulus-specific perceptual learning Ali Hashemi[1](hashea@mcmaster.ca), Jordan W. Lass[1], David Truong[1], Allison B. Sekuler[1], Patrick J. Bennett[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University

Practice in perceptual tasks over hundreds or thousands of trials often leads to long-lasting improvements in performance that generalize only partially to new stimuli. However, the time courses of the general and stimulus-specific aspects of learning are still debated. Some researchers argue that general aspects of the task are learned first in an initial rapid phase of learning and that stimulus-specificity emerges more slowly. In contrast, Hussain et al. (Front Psychol. 2012; 3:226) reported that 105 trials in a 10-AFC face identification task on Day 1 was sufficient to produce stimulus-specific learning in a test phase on Day 2, suggesting that stimulus-specific improvements can emerge rapidly. The current experiments extend these findings by examining 1) whether similar, rapid stimulus-specific learning occurs in a 10-AFC texture identification task; 2) if this rapid stimulus-specificity is long-lasting by increasing the interval between Days 1 and 2 from 24 hours to 1 week; and 3) the effects of reducing practice on Day 1 from 840 to just 21 trials. On Day 1, subjects performed a 10-AFC identification task with bandpass random textures embedded in three levels of external noise. The textures were presented at 7 contrasts that spanned the threshold range; hence the signal-to-noise ratio varied significantly across trials. On Day 2, subjects performed the task with the same or a novel set of textures. The dependent variable was response accuracy, and stimulus-specificity was measured by comparing performance with the same and novel textures on Day 2. We found stimulus-specific learning in subjects who received 840, 105, and 63 trials of practice, but not in subjects who received 21 trials of practice. Our results are consistent with the idea that stimulus-specific learning can emerge rapidly during practice and that this rapid learning is long lasting.

Acknowledgement: NSERC

54.16, *3:45 pm*

Spatial Specificity in a 3-dot Hyperacuity Task after Double Training Shao-Chin Hung[1](shung004@student.ucr.edu), Aaron Seitz[2]; [1]Neuroscience department, UC Riverside, [2]Psychology department, UC Riverside

Perceptual learning (PL), experience induced gains in discriminating sensory features, has been classically thought to be highly specific to trained retinal location of the stimuli. However, recent research from multiple labs has demonstrated that double training (Xiao et al., 2008) promotes dramatic generalization to untrained locations in paradigms previously considered to produce location-specific learning. While double training studies demonstrate that location specificity may have been misconstrued in some experimental contexts, there exists significant controversy regarding the extent to which double training will promote spatial generalization across different perceptual learning paradigms. To explore this issue, we examined spatial specificity in two different hyperacuity tasks. The first task was previously used by Zhang et al.(2011) to show that double training at the same location with a Vernier-acuity task and an orientation task, could transfer the learning of Vernier task to untrained locations. We replicated Zhang et al. findings under a gaze-contingent display, and found that double training at the same location enabled Vernier learning (either with Gabor or line stimuli) to transfer over untrained locations. We next examined whether this double training would also lead to spatial transfer of learning in a 3-dot hyperacuity task, which has been shown as a location-specific task in our previous study (Hung and Seitz, 2011). We found that learning in the 3-dot hyperacuity task showed no transfer to untrained locations under the same training paradigm. Our results show that the location specificity in PL is not ubiquitously decoupled after double training. We suggest that specificity of learning can arise from decision rules, attention learning, or representational changes and that small differences in the training approach can emphasize some of these mechanisms over the others.

Acknowledgement: NSF grant NSF (BCS-1057625) Dissertation Year Fellowship in UCR

54.17, *4:00 pm*

Push-pull training suppresses the interocular suppression in amblyopic vision Jun-Yun Zhang[1](zhangjy1982@gmail.com), Yu-Xiang Yang[1], Stanley Klein[2], Dennis Levi[2], Cong Yu[1]; [1]Department of Psychology and Peking-Tsinghua Center for Life Sciences, Peking University, [2]School of Optometry and Helen Wills Neuroscience Institute, UC Berkeley

Purpose: Amblyopia is characterized by poor visual acuity in the amblyopic eye (AE) and degraded stereoacuity. Perceptual learning, in which observers practice visual discrimination with their AEs, improves these visual functions to some degree. Here we asked whether a push-pull training method would reduce interocular suppression, in order to further improve visual acuity and stereoacuity in amblyopes who have previously participated in many hours of perceptual learning experiments. Methods: In push-pull training, AE practiced contrast discrimination with two 45° Gabors (SF=1/2 cutoff frequency) whose contrasts differed by 1.5 times threshold while non-amblyopic eye (NAE) was presented with bandpass noise (centered at 1/2 cutoff frequency). A staircase measured the tolerable noise contrast in NAE to allow successful contrast discrimination in AE during push-pull training. In pre- and post-tests, AE and NAE stimuli were switched to measure the tolerable noise contrast in AE. Interocular suppression was defined by the difference between AE and NAE tolerable noise contrasts. Results: After 10-days (20-hrs) training, interocular suppression was reduced by 57.3% ($p<0.001$). This reduction was specific to the trained orientation (12.9% improvement with 135° Gabors, $p=0.36$) and task (0.3% improvement in tumbling-E orientation judgment, $p=0.43$), but the tolerable noise contrast in NAE was reduced by 49.3% ($p=0.015$) with a new bandpass noise at a 2-octave lower center frequency. Stereoacuity was improved by 25.2% ($p=0.001$), on top of the 54.7% improvement after perceptual learning, but AE visual acuity was not further improved (by 1.5%, $p=0.33$). Conclusion: Our results show that push-pull training can suppress interocular suppression in an orientation and task specific manner in amblyopes even after many hours of previous perceptual learning experiments. Push-pull training further improves stereoacuity, but has no extra impact on AE visual acuity.

Scene perception

Tuesday, May 14, 2:30 - 4:15 pm

Talk Session, Royal Ballroom 4-5

Moderator: Michelle Greene

54.21, *2:30 pm*

Discovering mental representations of complex natural scenes

Michelle Greene[1](mrgreene@stanford.edu), Abraham Botros[1], Diane Beck[2], Li Fei-Fei[1]; [1]Stanford University, [2]University of Illinois

Human observers can rapidly categorize natural images, but the mechanism behind this ability is still unknown. Some models posit that categorization is aided by the use of internal representations, deployed in a top-down manner to constrain visual input. What is the content of these representations? Although internal representations have been obtained for simple stimuli using reverse correlation, these techniques are not generally scalable to the complexity of real-world scenes. Here, we introduce a novel type of naturalistic visual noise along with a method for efficiently traversing the noise space to reveal internal representations of real-world scenes. Visual noise was created by sampling from real-world scene features: an 8800-scene database was represented using multi-scale Gabor wavelets. Principal components analysis was performed on this representation, and noise patterns were created by reconstructing random values for the first 2500 principal components. This noise contains extended structures found in natural images, but without recognizable objects or textures. Observers were given a target image (Experiment 1) or scene category (Experiment 2), then presented with pairs of noise images, and instructed to choose the noise image most similar to the target. As no scene information was present in these images, observers had to use their internal knowledge of the target, matching it with the visual features in the noise. Subsequent trials were based on previously chosen images to efficiently explore the space. After each block, observers would rank chosen images, and the resulting reconstructed representation was created by weighting the chosen images with their rankings. The reconstructed images were found to be more similar to target images than targets from other blocks. Furthermore, reconstructions of scene categories were similar to the category average image, suggesting that internal scene category representations may reflect a composite of experienced exemplars.

54.22, *2:45 pm*

Match-On-Action: The role of motion and audio in limiting awareness of film cuts. Tim J. Smith[1](tj.smith@bbk.ac.uk), Janet Yvonne Martin-Portugues Santacreu[1]; [1]Department of Psychological Sciences, Birkbeck, University of London

Change blindness has been demonstrated for objects and the visual form of whole scenes but one of the most striking and common examples of change blindness is our difficulty to detect cuts in an edited moving image. Edit Blindness (Smith & Henderson, JEMR, 2008) can be created by adhering to the continuity editing conventions of Hollywood such as coinciding a cut with a sudden onset of motion (Match-On-Action). In this study we isolated the roles motion and audio play in limiting awareness of match-on-action cuts by re-editing existing feature film clips. Motion before and/or after the cut was removed and presented within twenty second film clips either with their original soundtrack or in silence. Participants were instructed to detect all cuts as quickly as possible. Cut detection times for intact cuts were significantly longer than all other conditions and removing either motion before or after the cut resulted in longer RTs than removing both. Percentage of missed cuts was higher for intact cuts than any other condition, although this effect lessened when audio was removed. In a follow-on eyetracking study, the pattern of cut detection times and missed cuts was replicated and analysis of saccade frequencies revealed a delay in orienting to the new shot following intact cuts compared to the rapid orienting (~300ms) observed when pre and post-cut motion was removed. The presence of motion either before or after the cut also decreased saccade frequency but only when accompanied by audio. These results suggest that film editors intuited the power of motion to attract viewer attention and obscure the timing of a cut. The results also emphasise the role of audio in maximising visual continuity. These ideas are consolidated in the Attentional Theory of Cinematic Continuity (Smith, Projections, 2012).

54.23, *3:00 pm*

Perceptual consequences of temporal modulations resulting from eye movements Marco Boi[1](boi@bu.edu), Martina Poletti[1], Michele Rucci[1,2]; [1]Department of Psychology, Boston University, [2]Graduate Program in Neuroscience, Boston University

During normal viewing, saccades alternate with fixational eye movements, yielding complex patterns of temporal modulations in the retinal input. Although it is well known that the visual system is highly sensitive to temporal changes, it is unclear how the modulations resulting from eye movements affect spatial vision. To address this question, we measured contrast thresholds in a forced choice task in which subjects reported the orientation of a grating (±45o) during natural post-saccadic fixation. The grating was either at low (1 cpd) or high spatial frequencies (10 cpd) and appeared while the saccade was in flight. To examine the effects of saccade transients, we first substituted the normal abrupt input change caused by saccades (normal condition) with a slow increment in contrast (1.5 s) starting at the very end of the saccade (no-transient condition). Elimination of the saccadic transient impaired sensitivity at low spatial frequency, but had no effect at high spatial frequency. We then examined how sensitivity evolves during the course of normal post-saccadic fixation by changing the duration of the post-saccadic presentation (100 ms or 800 ms). To replicate the visual input that occurs during natural viewing, gratings were embedded in a noise field with a 1/f spectrum (f spatial frequency) which covered the entire display. Sensitivity for low spatial frequencies did not change during the course of fixation, whereas sensitivity to high spatial frequencies increased significantly. In agreement with previous results (Rucci et al., 2007), elimination of the temporal modulations resulting from fixational eye movements yielded a 20% decrease in sensitivity at high spatial frequencies and no change at low spatial frequency. These findings indicate that the interplay between macroscopic and microscopic eye movements contribute to a-coarse-to-fine dynamics of visual processing during natural fixation.

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54.24, *3:15 pm*

Differential Connectivity Within the Parahippocampal Place Area

Christopher Baldassano[1](chrisb33@cs.stanford.edu), 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

The Parahippocampal Place Area (PPA) has traditionally been considered a homogeneous region of interest, but recent evidence from both human studies and animal models has suggested that PPA may be composed of functionally distinct subunits. Macaque parahippocampal cortex exhibits its distinctive changes in connectivity along the anterior-posterior axis, suggesting that anterior and posterior segments of human PPA might also have differential connectivity properties. To investigate this hypothesis, we utilize a functional connectivity measure for fMRI that can estimate connectivity differences at the voxel level. Applying this method to whole-brain data from two experiments, we provide the first direct evidence that anterior and posterior PPA exhibit distinct connectivity patterns. Anterior PPA is more strongly connected to regions in the default mode network, including the parieto-medial temporal pathway consisting of the caudal Inferior Parietal Lobule (cIPL) and Retrosplenial Cortex (RSC). Posterior PPA is more strongly connected to occipital visual regions, including the Lateral Occipital Complex (LOC) and the Transverse Occipital Sulcus (TOS). We further show that object sensitivity in PPA also has an anterior-posterior gradient, with stronger responses to images of abstract sculptures in posterior PPA than in anterior PPA. Our findings not only reinforce the link between PPA and macaque parahippocampal regions, but also demonstrate that PPA is actually composed of at least two regions operating on different types of visual information, shedding new light on the controversy over its functional properties.

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54.25, *3:30 pm*

Neural representation of the navigability in a scene Soojin Park[1](park@cogsci.jhu.edu), Matthew Levine[1], Matthew Dunne[1]; [1]Department of Cognitive Science, Johns Hopkins University

Navigating diverse environments is essential to an individual's everyday life. The ability to recognize the best route to take, where obstacles are, the affordance of the obstacles, etc., can influence our functional interactions and navigation in an environment. Here, we examined how neural areas respond to scenes that vary in the degree of navigability. Participants (N=11) were shown blocks of natural outdoor scenes defined by their functional (navigable vs non-navigable) and structural (open vs closed) properties: Open Navigable, Open Non-Navigable, Closed Navigable, & Closed Non-Navigable scenes. While participants performed a simple one-back task, we measured multivoxel pattern activity across regions of interests (the parahippocampal place area (PPA), the restrosplenial cortex (RSC), transverse occipital sulcus (TOS) and V1). We ran a linear classifier for these regions and analyzed the patterns of confusion errors. Depending on whether scenes are represented based on structural or functional properties, we would expect high confusion errors in scenes that share the same spatial structure or the same navigability, respectively. PPA did not show any bias in the percentage of confusion errors for scenes that share the same navigability or the same structure, suggesting that PPA represents both the structural and functional properties of scenes. In contrast, both RSC and TOS showed a significantly greater percentage of confusion errors for scenes that share the same navigability than for scenes that share the same spatial structure (both ps<.01). There was a significant interaction across regions and confusion error patterns (all ps<.03). These results suggest that RSC and TOS primarily represent the functional property of a scene, independent of the spatial structural property. Further analysis with individual differences showed that good navigators and poor navigators show significant difference in TOS confusion error patterns (p<.01), suggesting a possible role of TOS in computing the navigability of a scene.

54.26, *3:45 pm*

The posterior part of the lateral occipital complex analyzes the spatial correlation structure of natural visual scenes. H.Steven Scholte[1](h.s.scholte@uva.nl), Ilja Sligte[1], Iris Groen[1], Victor Lamme[1], Sennay Ghebreab[2]; [1]Department of Brain & Cognition, University of Amsterdam, [2]Institute for Informatics, University of Amsterdam

The spatial correlation (SC) structure of a scene is highly informative about its content. For instance, if the SC structure is high, you are probably dealing with a scene with coherent figure-ground segmentation. Yet, when it is low, you are most likely looking at a very cluttered scene (Scholte et al., 2009). By fitting a Weibull distribution to the contrast histogram of an image, one can estimate two free parameters - beta and gamma, where beta closely resembles the contrast energy present in the image, while gamma is indicative of the SC structure of the scene. In recent work, we have shown that it is neurally feasible to estimate gamma from the pooled activity of lower-tier neuronal populations (Scholte et al., 2009). Here, we study to what extent the lateral occipital complex (LOC) of the visual cortex may be the locus of such computations. In a first experiment we established that BOLD-MRI activity in LOC evoked by natural scenes is well described by the gamma parameter. In a second experiment wwe observed that activity in LOC was sensitive to artificial stimuli that only differed in their gamma parameter. Retinotopic mapping showed that sensitivity to gamma is particularly pronounced in the posterior part of LOC (LO1/LO2). These data suggest that the posterior part of LO represents the spatial correlation of natural scenes, which provide a fast and efficient mechanism for analyzing the structure of the scene as a whole. We believe that this sheds new light on the proposed functions of the LOC in vision.

54.27, *4:00 pm*

Neural correlates of affective judgments with visual stimuli Kleovoulos Tsourides[1](tsourk@mit.edu), Evan Ehrenberg[1], Christopher Simons[2], Pawan Sinha[1]; [1]Massachusetts Institute of Technology, [2]Givaudan

Our perception of many visual stimuli is accompanied by implicit or explicit assessments of how 'likable' they are. An image of a bowl of cherries, for instance, is attractive while one of moldy bread is not. Here we report results from our electrophysiological studies that were designed to identify the neural correlates of these judgments. Our stimuli depicted food or non-food items with sub-classes of appealing or unappealing exemplars. We sought to determine whether these four classes of stimuli could be distinguished based on the patterns of brain activity they elicited, the consistency of responses across subjects, as well as the time-course of emergence of these responses. Subjects passively viewed 200 visual stimuli (50 from each class) while their brain activity was recorded using magneto-encephalography (MEG). We found compelling differences in brain activity patterns corresponding to the four stimulus classes, with the first distinction emerging as early as 85 ms post stimulus onset. The identification of these neural correlates furthers our understanding of the substrates of affective judgments and has applied implications in the domains of design and evaluation.

Acknowledgement: Givaudan

Visual awareness

Tuesday, May 14, 5:15 - 7:15 pm

Talk Session, Royal Ballroom 1-3

Moderator: Rachel Denison

55.11, *5:15 pm*

Unconscious orientation exposure in TPE training enables transfer of foveal orientation learning to orthogonal orientations Ying-Zi Xiong[1](xyz7974001@yahoo.cn), Jun-Yun Zhang[1], Cong Yu[1]; [1]Department of Psychology and Peking-Tsinghua Center for Life Sciences, Peking University, Beijing, China

Foveal orientation discrimination learning can transfer completely to an orthogonal orientation with training-plus-exposure (TPE) training, in which the observers practice one orientation while being exposed to an orthogonal transfer orientation in an irrelevant task (Zhang et al., JN2010). We propose that perceptual learning is high level, but multi-session training and focused attention at the trained orientation may suppress untrained orientation, which blocks learning transfer. It is the exposure that reactivates the suppressed orientation inputs, so that high-level learning can connect to these inputs to allow learning transfer. Here we show that the exposure is equally effective without awareness. Specifically, an observer either practiced Gabor orientation discrimination (126o/36o, 1.5cpd/6 cpd, 0.47 contrast) or was exposed to the orthogonal Gabor (36o/126o) in one same eye in alternating blocks of trials. In the exposure condition the observers judged whether the stimulus was a Gabor or a letter C while the fellow eye was presented with flashing white noise to suppress the awareness of the Gabor/C stimulus, which led to chance-level performance. However, learning still transferred completely to the orthogonal orientation, suggesting that the exposure enabled learning transfer without stimulus awareness. Learning did not transfer in a control condition in which no Gabor/C stimulus was present, although the observers were unaware of the stimulus absence due to flashing noise suppression, so the transfer could not result from the presence of the flashing noise. These results suggest that the exposure part of TPE training requires no conscious monitoring and attentional modulation. The unconscious orientation exposure may reactivate V1 inputs representing the transfer orientation that are likely suppressed by training-related focused feature attention on a different orientation, which establishes functional connections between high-level learning and the untrained orientation to allow learning transfer.

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55.12, *5:30 pm*

Motion-induced blindness without awareness or attention Kevin Dieter[1](kdieter@bcs.rochester.edu), Duje Tadin[1,2], Joel Pearson[3]; [1]Center for Visual Science & Dept. of Brain and Cognitive Sciences, University of Rochester, [2]Department of Ophthalmology, University of Rochester, [3]School of Psychology, The University of New South Wales, Sydney, Australia

One of the most compelling visual phenomena is motion-induced blindness (MIB; Bonneh et al. 2001), a paradigm in which a distinctly visible stimulus (yellow dot) is made to periodically disappear by its placement within an otherwise coherently moving pattern (rotating blue crosses). MIB has been widely utilized to investigate the neural and cognitive mechanisms responsible for visual awareness. We wondered whether MIB might in fact occur outside of awareness and attention. Following an approach related to that used to study inattention and binocular rivalry (Brascamp & Blake 2012), we probed observers' (n=8) perceptual states after periods during which MIB was presented outside of awareness (suppressed by continuous flash suppression), was unattended (due to a concurrent rapid serial visual presentation task), or both. If the representation of the target fluctuates during this manipulation period (even without awareness and/or attention), it should sometimes be perceptually suppressed after this period due to MIB, resulting in longer reaction times (RT) to report the target item. We found that our manipulations (CFS and/or inattention) had no significant effect on RTs for detecting the target ($F_{3,21}=0.08$, $p=0.97$). This suggests that the dynamics of MIB were unaffected by removing awareness, attention, or both. We also devised a baseline condition in which the target dot was physically absent during the manipulation period. In the case of CFS, this condition was perceptually identical to the main condition. Nevertheless, baseline RTs were reliably faster for all of our manipulations, including CFS ($F_{1,7}=22.37$, $p<0.005$). Finally, to ensure that target suppression was due to MIB and not CFS, we ran a control in which the normally rotating MIB pattern was stationary and found no effect of CFS ($t_7=-0.94$, $p=0.38$). Taken together, these results suggest that the phenomenon of motion-induced blindness is unaffected by the removal of awareness, attention, or both.

Acknowledgement: T32 EY007125 from the NIH NEI

55.13, *5:45 pm*

Visual statistical learning guides perceptual selection Rachel Denison[1](rdenison@berkeley.edu), Maxwell Schram[1], Jacob Sheynin[1], Michael Silver[1,2]; [1]Helen Wills Neuroscience Institute, University of California, Berkeley, [2]School of Optometry, University of California, Berkeley

The visual system is primed to exploit temporal patterns in the visual environment. Humans can rapidly learn statistical dependencies between sequentially presented images without conscious intention or effort, a phenomenon called visual statistical learning. The consequences of statistical learning for subsequent perception, however, are largely unknown. To investigate the perceptual effects of visual statistical learning, we used binocular rivalry to measure the perceptual biases induced by learning sequences of natural images. Participants first viewed three-item image sequences (triplets) with sequential structure at both the image and category levels. In separate groups of participants, we manipulated the allocation of attention to images or categories during exposure. Next, participants performed a rivalry test. On each trial, the first two images from a learned triplet were presented unambiguously to the two eyes. A rivalry display immediately followed, in which the third image from the learned triplet was presented to one eye and the third image from a different triplet was presented to the other eye. We found that perceptual selection of an image in a given rivalrous pair depended on whether it was the image or category predicted by the preceding two unambiguous images. Further, the allocation of attention to images or categories during the exposure period influenced the strength of the subsequent rivalry effects. We confirmed that our attention manipulation affected the degree of statistical learning for images and categories with a 2AFC post-test in which participants judged the familiarity of trained vs. foil triplets. Our results show that recent, arbitrary visual statistical learning can alter subsequent perceptual selection. Such effects cannot be due to low-level priming or adaptation and provide evidence for flexible integration of visual memory with incoming sensory information in perception.

Acknowledgement: NSF Graduate Research Fellowship

55.14, *6:00 pm*

Knowing where without knowing what: partial awareness and high-level processing in continuous flash suppression Liad Mudrik[1](liadmu@gmail.com), Hagar Gelbard-Sagiv[1], Nathan Faivre[1], Christof Koch[1]; [1]California Institute of Technology

The scope of unconscious processing has been widely debated. Recently, more evidence for unconscious high-level processing was reported, mainly using continuous flash suppression (CFS). In CFS, Mondrian patches are flashed to the dominant eye while a static object is presented to the other eye. Despite the strong suppression induced, we found it allows prolonged periods of partial awareness: 2-6 seconds before subjects reported seeing the suppressed object, they were able to accurately localize it (at either the right or the left side of the visual field). Critically, when the display was stopped immediately after object localization, subjects were at chance for classifying it as a food or non-food item. In a second experiment, we asked whether such partial awareness could explain some of the previously reported high-level processing during CFS. We suppressed the perception of famous and non-famous faces (primes), presented at either the right or the left visual hemifield for 1.5s. The same or a different face (target) appeared immediately thereafter for 0.7s at the center of the screen, enlarged by 20%. Subjects were first asked to classify the target as famous or not, and then to indicate the prime's location and rate their confidence regarding the location on a scale of 1-4. A clear separation between localization and classification was again found, so that in about third of the trials, subjects could localize the face but not classify it. Critically, only at this stage of partial awareness an adaptation effect for the target occurred; no adaptation was found during complete unconscious processing, when subjects could not classify nor localize the prime. As expected, when subjects were able to do both priming was found. Our results call for a better objective measure for awareness, and put former findings of unconscious priming and adaptation in CFS into question.

Acknowledgement: HFSP, Fyssen, Mathers

55.15, *6:15 pm*

Binding-by-bursting: A new theory of attentional binding and the neural correlates of consciousness

Peter Tse[1](Peter.U.Tse@dartmouth.edu); [1]Dept. Psychological and Brain Sciences, Dartmouth College

I will review neurophysiological evidence supporting the view that endogenous attentional binding consists in transitioning a neural circuit from a tonic to a phasic mode of firing via cholinergic feedback from the basal forebrain and other areas, characterized by an increased probability of burst transmission up and down the ventral pathway. Binding-by-bursting emphasizes decorrelation in firing (Cohen & Maunsell, 2009, 2011) and an increase in bursting (Anderson et al., 2011) over synchronous firing. On this view, increased power of gamma oscillations with attention (Fries et al., 1997, 2001a,b, 2002, 2007, 2008; Gray, 1999; Singer, 1999a,b, 2004; Uhlhaas et al., 2009) arises not primarily from synchronous firing, although synchronous bursting is important; it arises from the synchronous subthreshold inputs to postsynaptic neurons imposed by the inhibitory interneuron "clock" (Buzsáki & Chrobak, 1995; Bartos et al., 2007; Kawaguchi et al., 1987). What "binding by bursting" provides is not the gluing of features together at a location, but rather the complete information-processing treatment of the entire hierarchical circuit within the attended domain. Processing outside of the attended domain does not receive a circuit's complete information-processing treatment because it remains in tonic firing mode, and may undergo burst suppression. If single spikes are "filtered out" (Lisman, 1997), then downstream neurons will not respond well to tonic input, unless it arrives synchronously. Entering phasic mode enhances information processing, especially in later stages of a hierarchy, because burst packets corresponding to a given bottom-level input will propagate the entire hierarchy in a coherent sequence. Thus, detected information will be processed from beginning to end, or bottom to top of an information-processing 'stack,' in the case of the ventral pathway, up to recognition. Particular emphasis will be placed on the importance of onset transients in opening NMDA receptors. The theory is detailed in Tse (2013, MIT Press).

55.16, *6:30 pm*

Emergence of illusory shapes from invisible inducers

Marjan Persuh[1,2](mpersuh@gmail.com), Tatiana Aloi Emmanouil[1], Tony Ro[1,2]; [1]Department of Psychology, The City College of the City University of New York, [2]Program in Cognitive Neuroscience, Graduate Center of the City University of New York

Several studies have claimed that unconscious vision is fast, automatic, and involves simpler forms of information processing compared to conscious perception. However, to render stimuli unconscious, experimenters often use brief stimulus presentation times and other manipulations that impair visual processing, which confounds awareness with differences in physical stimulus attributes and neural processing. In the current study, we developed a novel method to render visual stimuli invisible, while allowing for their extended processing. We demonstrate the validity of the method by showing that illusory contours are consciously perceived even when all inducing elements are rendered invisible, contrary to previous reports. In the first experiment we presented inducers, either alone or followed by a pattern mask. We varied the number of inducer-mask repetitions (1-8) and showed that with repeated exposure, participants started to perceive illusory contours even though they were completely unaware of the inducing elements in the masked condition. In the second experiment we used only the highest number of repetitions (8) and showed that the perception of illusory contours was similar regardless of whether the inducers were masked or not, even though forced-choice discrimination of the inducers was at chance. These results demonstrate that with repeated presentations, the processing of stimuli presented below the threshold for awareness may be cumulative and more extensive than previously considered. Our study thus suggests that consciousness research should fundamentally shift to using methods that effectively block stimuli from awareness while minimally interfering with their processing.

55.17, *6:45 pm*

High-level visual processing despite lack of awareness: Evidence from event-related potentials in a case of selective metamorphopsia

Teresa Schubert[1](schubert@cogsci.jhu.edu), David Rothlein[1], Trevor Brothers[2], Kerry LeDoux[3], Barry Gordon[3], Michael McCloskey[1]; [1]Department of Cognitive Science, Johns Hopkins University, [2]Center for Mind and Brain, University of California at Davis, [3]Cognitive Neurology/Neuropsychology, Johns Hopkins University

We report a patient, RFS, with a category-specific metamorphopsia for Arabic digits. MRI shows parietal atrophy; concurrent motor and memory deficits support a diagnosis of cortico-basal degeneration. RFS's recognition, writing, and mental imagery of Arabic digits are dramatically impaired, yet semantic knowledge of number quantities is intact. Digit forms are perceived as grossly distorted and the digits distort other stimuli (e.g., faces or words) in the spatial or temporal vicinity, rendering RFS unaware of their identity or form. For example, RFS cannot report whether a stimulus embedded in a large 8 is an intact or scrambled face. We probed whether stimuli embedded in digits are processed despite RFS's inability to perceive them. Results from three event-related potential (ERP) experiments indicate that the identity of stimuli embedded in large digits are processed despite RFS's distorted perceptual experience. First, faces embedded in digits elicited a reliable N170 response (relative to scrambled faces), indicating visual processing sufficient to distinguish faces from scrambled faces. Second, target words embedded in digits elicited a reliable P300 response (relative to non-target words). Finally, a reliable N400 response was elicited in response to incongruency between an auditory word and a written word embedded in a digit. These findings support the hypothesis that word stimuli presented over digits are processed to the level of amodal lexical representations without conscious awareness. The results are consistent with theories of conscious awareness which posit obligatory feedback/recurrent processing underlying coherent visual percepts.

55.18, *7:00 pm*

Making the switch: Transient unconscious cues can disambiguate bistable images

Emily Ward[1](emily.ward@yale.edu), Brian Scholl[1]; [1]Department of Psychology, Yale University

What we see is a function not only of incoming stimulation, but of unconscious inferences in visual processing. Perhaps the most powerful demonstrations of this are bistable images, wherein the same stimulus alternates between two very different percepts, corresponding to two competing stable states of an underlying dynamic system. What causes the percepts to switch? Previous research has implicated voluntary effort (e.g. mediated by attention) and stochastic processing. Here we explore a third possibility, wherein percepts may switch as a result of data-driven manipulations, even when those manipulations are brief and observers are unaware of them. This is difficult to study with most bistable images, since the percepts are so volatile and the switching so frequent. A notable exception is the Spinning Dancer animation: a spinning woman is depicted in silhouette, so both her orientation in depth and direction of rotation are ambiguous. Still, many observers see her rotating in the same direction for long periods of time, interrupted only rarely by involuntary switches. We introduced disambiguating information into this display, in the form of explicit contours on the silhouette that indicated occlusion (e.g. which leg is behind the other). These contours were subtle and presented quickly enough that most observers failed to notice them throughout the entire experiment. Nevertheless, their impact on switching was strong and systematic: the cue typically led to a perceptual switch shortly thereafter, especially for contours that conflicted with the observer's current percept. Yet to the observers, the switches seemed stochastic. These results show not only how transient disruptions can shock a stochastic system into a new stable state, but also how the visual inferences that determine perception extract the content of incoming visual information to constrain conscious percepts — even when neither the content nor the brute existence of that information ever reaches awareness.

Face perception: Neural mechanisms

Tuesday, May 14, 5:15 - 7:15 pm

Talk Session, Royal Ballroom 4-5

Moderator: Nikolaus Kriegeskorte

55.21, *5:15 pm*

The face network estimated by intrinsic functional connectivity employing a large sample (N = 296) Lúcia Garrido[1](garridolucia@gmail.com), Avram Holmes[1], Marisa Hollinshead[1], Randy Buckner[1], Ken Nakayama[1]; [1]Department of Psychology, Harvard University

Previous studies relying on small samples and using resting state functional MRI have shown that the fusiform face area (FFA) is connected to other face responsive regions (Turk-Browne et al., 2010; Zhang et al., 2009). Here, we used a sample of 296 participants to estimate connectivity maps from each region of the "core system" of face processing (Haxby et al., 2000) and quantify the coupling of these regions to make inferences about their organization. For each participant, we computed the correlation between the time series of seed regions corresponding to the face core system (FFA, occipital face area (OFA), and superior temporal sulcus (STS)) with that of each other voxel in the brain. Seed regions were defined based on peak MNI coordinates from previous studies. We averaged connectivity maps for each seed region across sub-samples of about 50 participants each. For each region of the face core system, we observed consistent connectivity maps across each independent sub-sample. We further estimated the magnitude of correlations between the core regions and found preferential coupling of the STS with the FFA, relative to the OFA, thus suggesting a revision of models (Haxby et al., 2000) of the organization of these regions. Finally, we tested seven participants using both resting-state fMRI and a functional localizer. Average connectivity maps from individually defined face-responsive regions in these participants were consistent to the maps estimated in the larger samples, and there was also preferential coupling of FFA and STS in comparison to that between OFA and STS. These analyses reveal the intrinsic connectivity among the FFA, OFA and STS, as well as the connections between each of these regions and the rest of the brain, providing novel insights into the organization of the face recognition system.

55.22, *5:30 pm*

A novel functional connectivity analysis of the development of face-processing networks: Independent component analysis of task and resting-state data Maha Adamo[1](madamo@ucsd.edu), Frank Haist[1,2,3]; [1]Center for Human Development, University of California, San Diego, [2]Department of Psychiatry, University of California, San Diego, [3]Kavli Center for Mind and Brain, University of California, San Diego

Face-processing expertise within the core face network, including the fusiform face area, occipital face area, and superior temporal gyrus, does not reach maturity from a regional or functional connectivity perspective until mid-adolescence. However, there is virtually no data regarding the development of functional networks within the extended face network, including the amygdala, insula, inferior frontal gyrus, anterior temporal pole and parietal cortex, which tend to be activated in a task-specific fashion in adults. Recently, we presented findings from a simple viewing task suggesting that children do not modulate face-related activity within the extended network according to task needs, and instead hyperactivate the entire extended network (Haist, et al., 2011 VSS Meeting; manuscript under review). Here, we present findings from a novel functional connectivity analysis of 71 participants from that study spanning from 7- to 38-years-old. Functional networks across our entire sample were modeled using independent component analysis (ICA). Face-preferential (Faces > Objects) independent components (ICs) were identified through multiple regression analysis using the IC BOLD signal time courses; the leading such component included activation in the fusiform gyrus and nearly every component of the extended face network. Each individual's activity corresponding to this IC was calculated and submitted to a regression against age, which showed that children hyperactivated the extended face-processing regions defined in this IC during the task. We subsequently analyzed the activity of this face network within resting-state data from these participants. Although the network was observable during rest, activation levels were similar for adults and children. These results show that modulation of activity within a coherent face network including the fusiform gyrus and extended face network undergoes protracted development. Furthermore, this network is engaged specifically during face viewing and is not ubiquitously hyperactivated in children. This is the first developmental study integrating task and resting-state functional connectivity measures.

Acknowledgement: R01 HD060595

55.23, *5:45 pm*

Neural Coding of Individual Faces in the Human Right Inferior Occipital Cortex: Direct Evidence from Intracerebral Recordings and Stimulations Jacques Jonas[1,2,3](jac.jonas@gmail.com), Bruno Rossion[4], Julien Krieg[3], Laurent Koessler[3], Sophie Colnat-Coulbois[5], Jean-Pierre Vignal[1,3], Médéric Descoins[6], Corentin Jacques[4], Hervé Vespignani[1,2,3], Louis Maillard[1,2,3]; [1]Service de Neurologie, Centre Hospitalier Universitaire de Nancy, France, [2]Faculté de Médecine de Nancy, Université de Lorraine, Nancy, France, [3]Centre de Recherche en Automatique de Nancy (CRAN), Université de Lorraine, UMR CNRS 7039, France, [4]Université Catholique de Louvain, Louvain-la-Neuve, Belgium, [5]Service de Neurochirurgie, Centre Hospitalier Universitaire de Nancy, Nancy, France, [6]INSERM U751 Epilepsie & Cognition, Marseille, France

Discriminating individual faces requires elaborate and refined perceptual skills call for by few other categories of objects. Yet, the neural basis of individual face coding in the human brain remains unknown. Here we were able to test for behavioral individual discrimination during transient inactivation of a face-selective area of the right inferior occipital gyrus ("occipital face area", OFA) in an epileptic patient implanted with intracerebral depth electrodes (patient KV described in Jonas et al., 2012). During electrical intracerebral stimulations of the rOFA, KV was presented with pairs of identical or slightly different (40%) morphs of unknown faces and was asked to tell if the 2 faces were different. Outside stimulations, she was almost flawless (49/54 trials). However, when stimulating one electrode contact (D5) in the rOFA (movies available), her performance dropped to 0% (0 of 6 trials). She clearly stated that there were no visual distortions that disturbed the task. Face-selective ERPs and gamma-ERSP responses were found at this contact, which was located within the rOFA defined in fMRI. Most importantly, evidence for strong sensitivity to individual faces was found at the contact D5 using fast (6 Hz) periodic visual stimulation of blocks of different or identical individual faces (Rossion & Boremanse, 2011). This effect was observed only at a few contiguous electrode contacts, but of all contacts (27 in the right ventral occipito-temporal cortex), the largest difference between the effect for upright and inverted faces was observed at D5. These findings provide the first evidence of transient impairment of individual face discrimination following electrical intracerebral stimulation, and point to a critical functional role of the right OFA in individual face perception (Schiltz & Rossion, 2006). These observations also support the functional relevance of visual adaptation effects obtained with high-level visual stimuli through fast periodic visual stimulation.

55.24, *6:00 pm*

The effect of fast periodic stimulation on the face-selective patches of the monkey superior temporal sulcus: An fMRI adaptation study Jessica Taubert[1,2], Francesco Gentile[1,3], Ivo D. Popivanov[2], Bruno Rossion[1], Rufin Vogels[2], Wim Vanduffel[24]; [1]Face Categorization Lab, University of Louvain, [2]Neurophysiology, KU Leuven, [3]University of Maastricht, [4]Harvard Med. Sch., Athinoula A. Martinos Ctr. for Biomed. Imaging, Massachusetts Gen. Hosp. Charlestown

A number of functional magnetic resonance imaging (fMRI) studies in humans have shown a decrease of neural activity in many areas of the occipito-temporal cortex when identical faces are repeated as compared to different faces. This adaptation effect has been used to infer that these areas are sensitive to differences between faces. More recently, a network of face patches have been identified in the monkey inferior temporal (IT) cortex using fMRI. In this study we tested whether these areas in monkey IT also show a decrease of activation when an individual face is repeated. The second purpose was to determine the optimal stimulation frequency rate at which such an effect would be observed. First, a whole-brain localizer was run on three monkeys, using the contrast agent enhanced fMRI technique. In agreement with previous studies, a comparison between faces and objects yielded multiple patches of activation in the superior temporal sulcus (STS). The subsequent fMR-adaptation experiment was comprised of 24 conditions (12 with an identical face; 12 with different faces). In each of these conditions, a face appeared and disappeared through a gray screen at a variable rate of stimulation (1-12 Hz). In an identical face condition, the same face was presented repeatedly. In a different faces condition, 10 individual faces appeared in a random order. All of the functionally defined face patches showed a larger response to blocks of different faces than when the same face was repeated. These effects were generally the largest when faces were presented at a rate of 5 Hz to 7 Hz suggesting that the face processing network was most sensitive to differences between faces when they were presented at these frequency rates. Electrophysiological experiments have been designed to investigate the response of single units in these fMRI defined patches, during this repeated stimulation task.

55.25, *6:15 pm*

Faciotopy – a face-feature map with face-like topology in the occipital face area Nikolaus Kriegeskorte[1](nikolaus.kriegeskorte@mrc-cbu.cam.ac.uk), Marieke Mur[1], Linda Henriksson[1,2]; [1]MRC Cognition and Brain Sciences Unit, Cambridge, UK, [2]Brain Research Unit, O.V. Lounasmaa Laboratory, Aalto University, Espoo, Finland

Brain imaging studies have suggested several brain regions specialized for face perception. However, the intrinsic functional organization of these regions and their status as cortical areas with clearly defined boundaries is unclear. Here we test for "faciotopy" in human face-selective brain regions, i.e. a face-feature map on the cortical surface, where cortical distances reflect the physical distance between the different face features. We measured responses to visual presentation of isolated face features with functional magnetic resonance imaging (fMRI). The features were extracted from frontal face photographs (12 in total) and included the left and right eyes, nose, mouth, ears, chin, and parts of the neck and hairline. Different exemplars of the different features were presented in an fMRI block design. All stimuli were shown in the center of the visual field. Primary visual cortex (V1), occipital face area (OFA) and fusiform face area (FFA) were localized in each individual (N=12) using independent localizer data. All regions-of-interest responded to the isolated face features, and their response patterns also distinguished between the features. In addition, OFA, but not V1, showed a substantial tolerance to retinal feature size. We compared the distances between the cortical face-feature representations to the physical distances between the features in a face, and found a significant faciotopic organization in both left and right OFA, but not in V1 or FFA. This finding suggests that OFA might be spatially organised as a single map of a face, with local patches detecting individual features with some degree of invariance. Faciotopy would be the first example, to our knowledge, of a cortical map reflecting the topology, not of a part of the organism itself (its retina in retinotopy, its body in somatotopy), but of an external object of particular perceptual significance.

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55.26, *6:30 pm*

A Neurocomputational Basis for Face Configural Effects Irving Biederman[1,2](bieder@usc.edu), Xiaokun Xu[1]; [1]Psychology, University of Southern California, [2]Neuroscience, University of Southern California

The representation of faces is said to be configural. But what could "configural" possibly mean in neurocomputational terms? If the coding of faces retains aspects of the original multiscale, multiorientation tuning characteristic of early visual stages (with allowance for translation and size invariance), then configural effects could be explained merely by the coding by medium and large scale V1-type kernels whose receptive fields are well modeled as Gabor filters. These kernels would cover large regions of the face independent of whether the variation in contrast was derived from part shapes, part distances, or the subtle sculpting of the smooth surfaces. Because of the overlap in receptive fields of these filters, alteration of a single shape of a part would not only affect a column of Gabors varying in scale and orientation (termed a Gabor "jet") whose r.f.s are centered on that part, but Gabors centered at distant parts of the face. We used the von der Malsburg Gabor-jet system (Lades et al., 1993), which captures essential aspects of hypercolumn V1 coding, to model the paradigmatic configural effect in faces (Tanaka & Farah, 1993): After learning a set of faces (generated from IdentiKit parts), recognition of the whole face, against a distractor differing only in the shape of a single face part (e.g., the nose), was more accurate than the recognition of that part in isolation. The Gabor-jet model yielded the same ordering, producing greater dissimilarity for whole faces compared to the single parts distinguishing those faces. The psychophysical discriminability of pairs of faces is almost perfectly predictable from a Gabor-jet similarity metric but the same capacity that allows for the coding of fine metric differences renders face individuation susceptible to inversion or contrast reversal.

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55.27, *6:45 pm*

What are you looking at? The necessity of Eye-tracking use in ERP face-research Thomas Anderson[1](t3anders@uwaterloo.ca), Dan Nemrodov[2], Frank Preston[1], Roxane Itier[1]; [1]University of Waterloo, [2]Université catholique de Louvain

The present study aimed to determine whether the N170, the most studied face-sensitive ERP component, and its known face inversion effect (FIE) are modulated by fixation within the face and whether eye-tracking should be employed as standard practice in face-research. Two ERP groups were tested in a face-orientation discrimination task. Faces were presented in such a way that the centered fixation cross was on specific facial features. Participants were instructed not to move their eyes away from the fixation cross. In the "trigger group", fixation was forced using eye-tracking fixation-triggers and trials contaminated by eye movements beyond 0.75° of visual angle around fixation were rejected. In the "natural group", no fixation-triggers were used and natural eye movements were recorded by the eye tracker. The second group thus mimicked classic ERP face studies where subjects are told to fixate on the cross yet eye position is not enforced. The eye-tracking data from the natural group revealed that although instructed to fixate on the cross, when not forced to do so participants' eyes strayed widely. Most importantly, the ERP data showed that fixation-location within the face modulated N170 amplitude and interacted with the FIE in the trigger group but not in the natural group. These results point to an increased probability of type-II error in classic face ERP studies due to the lack of eye-tracking use. Given the theoretical importance of modulations such as the N170 FIE for understanding face perception, these findings are not trivial methodological concerns. These data highlight the importance of recording EEG and eye-tracking simultaneously in face-research.

55.28, *7:00 pm*

A multichannel model of face processing based on self-organizing principles Guy Wallis[1](gwallis@hms.uq.edu.au); [1]Centre for Sensorimotor Neuroscience, School of Human Movement Studies, Faculty of Health Sciences, University of Queensland

Evidence from developmental, behavioral, and electrophysiological studies suggests that the recognition and representation of faces is subserved by specialist cortical processes and sub-regions, separate from those involved in object recognition. This dichotomy is reflected in a lack of overlap between models of face and object recognition. Models of face processing have traditionally focused on behaviors thought to be unique to face recognition such as the prototype, configural, and holistic effects, and face-specific adaptation after-effects. Currently, the most widely accepted theory of object recognition is based not on the norm-based encoding models of face processing, but rather, on abstract features whose size and complexity increase over a series of competitive, hierarchical stages. Despite the fundamentally piecewise nature of such a model, I explain how effects such as prototyping, configural and holistic coding, are all emergent properties of such a system when one considers the impact of learning. The ideas are backed up by novel behavioral results and simulation of an unsupervised competitive network. The results highlight how the peculiarities of face processing can be seen as an inevitable consequence of our intense exposure to faces.

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Tuesday Afternoon Posters

Attention: Spatial selection 2

Tuesday, May 14, 2:45 - 6:45 pm

Poster Session, Royal Ballroom 6-8

56.301 **Saccadic adaptation modulates inhibition of return** Farahnaz Ahmed Wick[1](farahnaz@gmail.com), Tyler Garaas[2], Marc Pomplun[1]; [1]University of Massachusetts Boston, Department of Computer Science, [2]Mitsubishi Electric Research Laboratories

Saccadic adaptation, a form of motor learning responsible for maintaining saccadic accuracy to targets, has been shown to additionally affect the distribution of attention when it is shifted to a location selected for a subsequent saccadic eye movement. In this study, we investigated the effective relationship between the alteration of attention associated with saccadic adaptation and inhibition of return (IOR), an inhibitory mechanism associated with covert orienting of attentional resources. IOR refers to the finding that response times are typically slower for targets at previously (SOA > 300 ms) cued locations than for targets at uncued locations. Previous studies have examined relationships involving IOR and distribution of saccadic latencies, deviation and fixation times. However, the exact mechanism linking saccade amplitudes and both the attentional and oculomotor biases of IOR is currently unknown. We hypothesized that when saccade amplitudes were modified, covert attentional shifts (Doré-Mazars & Collins, 2005; McFadden et al., 2001), attentional resource distribution (Ahmed Wick et al., under review) and oculomotor programming (see Hopp & Fuchs, 2004) to the cued location would be modified correspondingly. As a result, attentional shifts would miss the cued location and, therefore, receive less inhibition. In this study, we used the classic double-step paradigm to effect an increase (forward adaptation) or decrease (backward adaptation) in saccade amplitudes. Afterwards, we examined changes in IOR to cued and uncued targets at 5o and 10o in the left and right hemifield against a control condition using a within-subjects design. We found no IOR effects after both forward and backward adaptation, while significant IOR was observed in the control condition. These results indicate that a change in the oculomotor programming of saccades through saccadic adaptation affects not only saccadic amplitude and shifts of attention but also behavioral qualities related to the distribution of attentional resources.

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56.302 **Differential effects of road situations and driving behaviors on eye movements in experienced and novice drivers** Ling Li[1](liling@uestc.edu.cn), Zhenlan Jin[1], Dengmiao Yu[1]; [1]Key Laboratory for NeuroInformation of Ministry of Education, School of Life Science and Technology, University of Electronic Science and Technology of China

Traffic crash statistics have shown that novice drivers have more risks than those of experienced drivers, in which novice drivers may suffer from lower efficiency in attentional resource allocation when driving. Since eye movements are closely related to attentional resource allocation, the current study investigated effects of road situations and driving behaviors on driver's attention by measuring eye movements in both experienced and novice drivers. Subjects freely viewed traffic videos of three road situations (highway, suburb, and city road) with two driving behaviors (straight driving and lane changing), respectively. The subjects were required to imagine themselves as drivers while viewing videos and their eye movements were recorded. We found significant interaction between subject group, road condition and driving behaviors on fixation duration. The experienced drivers fixated longer than the novice drivers while viewing highway and suburb videos with straight driving and this discrepancy increased when comparing lane changing to straight driving. In addition, both groups of drivers did not differ in the city road within both driving behaviors. We also found significant interaction between subject group and driving behaviors on saccade amplitude. The experienced drivers showed saccades of smaller amplitudes than the novice drivers with both driving behaviors and the difference between subject groups enlarged in lane changing. These results show that different parameters of eye movements are affected variously by road and driving conditions differently for experienced and novice drivers, suggesting differential strategy of allocating attentional resource between both groups. These imply that the risks of novice drivers in driving may be reduced through attention training to achieve the mode of eye movements of experienced drivers.

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56.303 **The effect of local-global processing on contextual learning** Lauren Bellaera[1](L.Bellaera@warwick.ac.uk), Adrian von Mühlenen[1], Derrick Watson[1]; [1]University of Warwick

Repeated contexts allow us to find relevant information more easily. The ability to use such information has been called contextual learning and has been investigated using the contextual cuing paradigm. In this task, participants search for and identify the orientation of a target letter T amongst rotated Ls. Over blocks, RTs become faster for repeated spatial configurations (old displays) compared with novel configurations (new displays). Learning such repeated contexts has been proposed to depend on either global processing of the repeated contexts, or alternatively processing of the local region surrounding the target. The present study takes a novel approach by measuring differences in participant's attentional bias (i.e. local or global) in relation to the amount of contextual learning. Twenty participants completed a shape detection task followed by a contextual cueing task. In the shape detection task participants were presented with large shapes consisting of smaller shapes and they had to decide whether the target shape was present or absent. The presentation of the target shape could either be presented at the local level (i.e. the smaller shape) or the global level (i.e. the larger shape). In the contextual cuing task participants completed 16 blocks with 24 trials in each (12 old and 12 new displays). Participants were then split into two groups, depending on whether their local RT - global RT was below (local-bias group) or above (global-bias group) the median. Participants in the local-bias group showed significantly stronger contextual cueing effects than participants in the global-bias group (152 vs. 39 ms, respectively). Furthermore, there was a strong negative correlation between global bias and contextual cueing ($r = -0.61$, $p<.005$). In conclusion, this study suggests that contextual learning depends more on local information than on global information. Furthermore, it highlights the importance of observer variables in relation to contextual learning.

56.304 **EEG pattern classification reveals the scope of local vs. global attention** Alexandra List[1](a-list@northwestern.edu), Monica Rosenberg[2], Aleksandra Sherman[1], Marcia Grabowecky[1,3], Satoru Suzuki[1,3], Michael Esterman[4]; [1]Psychology Department, Northwestern University, [2]Psychology Department, Yale University, [3]Interdepartmental Neuroscience Program, Northwestern University, [4]Neuroimaging Research Center for Veterans, VA Boston Healthcare System

Pattern classification techniques have been widely used to differentiate neural activity associated with different perceptual, attentional, or cognitive states, especially using fMRI. Here, we endeavored to predict the scope of attention, local or global, from EEG data. A group of 15 participants were presented with Navon-type hierarchical stimuli and were asked to indicate which of two target letters (H or S) was presented, irrespective of whether the target appeared at the local or global level. On each trial, the target letter appeared equiprobably at each level, paired with an irrelevant distracter (E or A) at the other level. EEG data were recorded from 64 channels at a sampling rate of 1024 Hz, and were subsequently high-pass filtered at 0.1 Hz. We applied linear support vector machine (SVM) classifiers with a cross-validation procedure at each time-point (~1 ms). EEG data were reliably differentiated for local vs. global attention on a trial-by-trial basis, emerging as a specific spatiotemporal activation pattern over posterior electrode sites during the 300-700 ms interval after stimulus onset. Whereas the classifiers reliably differentiated the scope of attention, a more traditional event-related potential (ERP) analysis of the same data did not. In sum, multivariate pattern analysis of EEG, which reveals unique spatiotemporal patterns of electrophysiological activity distinguishing between behavioral states, is a highly sensitive tool for characterizing the neural correlates of attention.

Acknowledgement: NIH R01 EY018197

56.305 **The contribution of scene gist and spatial dependency of objects to semantic guidance of attention** Chia-Chien Wu[1](chiachie@cs.umb.edu), Hsueh-Cheng Wang[1], Marc Pomplun[1]; [1]Department of Computer Science, University of Massachusetts Boston

Recent studies have shown that, during natural viewing, humans tend to bring their gaze to the objects that are semantically similar either to the currently fixated one, or to the requested search target (Hwang et al., 2011). This result, however, may be confounded by knowledge of the scene gist, which does not require object recognition (Torralba et al., 2006), or by spatial dependency among objects (Oliva & Torralba, 2007). To clarify the contributions of these factors to semantic guidance, subjects were asked to view a series of displays with the scene gist removed. Each display was generated by segregating 15 objects from a natural scene in the LabelMe database. To remove the scene gist, all objects were pasted on a grey canvas. The objects were placed either at the same coordinates as in the original scene so that no scene gist but spatial dependency was provided (fixed condition), or at randomly selected locations on the canvas in order to also remove the spatial dependency (scrambled condition). The analysis was compared with a control condition using pseudo-randomly located "fixations." The result shows that, without scene gist, the preserved spatial dependency among objects (fixed condition) still provided additional semantic information and resulted in stronger semantic guidance (ROC = 0.68) than the scrambled condition (ROC = 0.6), in which both scene gist and spatial dependency were removed. Interestingly, in both conditions, semantic guidance was stronger than in the control condition (ROC = 0.5). Our results confirm the previous finding of semantic guidance and show that it is not entirely due to either the effect of scene gist, or to spatial dependency among objects. Even without scene gist or spatial dependency, subjects could still retrieve semantic information to guide their attention. This strategy may facilitate the efficiency of visual search and scene understanding.

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56.306 **3D spatial attention effects are independent of projected 2D size and location for older and younger observers**

Russell Pierce[1](rpier001@ucr.edu), G. John Andersen[1]; [1]Psychology, College of Humanities, Arts, and Social Sciences, University of California, Riverside

The majority of experiments on visual spatial attention have been conducted using stimuli positioned and extended in height and width (e.g., B. A. Eriksen & Eriksen, 1974; Posner, Snyder, & Davidson, 1980). However, several experiments have demonstrated that spatial attention varies as a function of depth for both younger and older observers (e.g. Andersen, 1990; Theeuwes, Atchley, & Kramer, 1998). In a recent experiment, we found that the shape of visual spatial attention in the horizontal and depth dimensions was different for older and younger observers (Pierce, Bian, & Andersen, VSS 2011). However, in that experiment the effect of two-dimensional (2D) projected size and position was not experimentally controlled. If spatial attention is 3D, then there should be an effect of target distance when 2D projected size and position are constant. The primary purpose of the current work was to assess this hypothesis. In the current experiment, observers detected a light-change target in an array of lights over a simulated roadway while they performed a car following task. We manipulated the size and position of light-change targets at different depths to hold the projected size and position of targets constant between blocks. Although projected size and position were identical in this experiment, we observed statistically significant differences in RT between targets at a simulated distance further from the observer (younger observers M = 718ms, SD = 246ms; older observers M = 894ms, SD = 287ms) and targets at a simulated distance closer to the observer (younger observers M = 570ms, SD = 137ms; older observers M = 712ms, SD = 190ms), $F(1, 46) = 72.09$, $p < .001$. These results demonstrate that 3D attention effects are not dependent on projected size or position, and that the mechanism of 3D attention is present in younger and older observers.

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56.307 **Previewing distractors reduce efficiency of visual processing at previewed locations**

Takayuki Osugi[1](tosugi@fechner.c.u-tokyo.ac.jp), Ikuya Murakami[1]; [1]Department of Life Sciences, The University of Tokyo

When some of distractors (old items) appear before others (new items) in an inefficient visual search task, the old items are excluded from the search (visual marking). Visual marking occurs possibly because the locations of the old items are inhibited before the new items appear. Sensitivity to contrast increments at the old locations has been shown to become lower than that at the new locations. What process plays a key role in reducing sensitivity? The present study took advantage of the equivalent noise analysis to examine whether the sensitivity reduction occurs due to an increase in internal equivalent noise (IEN) or due to a decrease in calculation efficiency (CE). To determine these parameters, we measured contrast thresholds for a Gaussian luminance blob as a function of external noise contrast. This detection task was combined with the preview search task in which the old items were presented for 1 s before the new items were added. The target to be searched for could be present only within the new items. At 200 ms after the onset of the new items, a blob appeared for 100 ms in half of all trials. All stimuli were embedded in various amounts of external noise, i.e., dynamic random luminance noise. Following speeded reaction for search, participants were asked to report whether a blob had appeared. The parameters estimated from the threshold versus noise contrast function indicated that CE at the old locations was lower than that at the new locations, whereas the IEN did not increase at the old locations. Therefore, the sensitivity reduction at the old location is attributable to the decrease in CE. Some inhibitory template for visual marking effectively operates by depriving previewed sterile locations of limited attentional resources, such as time and resolution, for target search.

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56.308 **Less of a Pop-Out? Spatial-VSTM is Critical For Priming of Pop-Out to Emerge.**

Alejandro Lleras[1](Alejandro.Lleras@gmail.com), JeeWon Ahn[1]; [1]Department of Psychology, College of Liberal Arts and Sciences, University of Illinois

Priming of Pop-out (PoP) refers to the observation that participants are quicker to orient to a pop-out item if the color of the current pop-out stimulus is the same as the color of the pop-out stimulus on the preceding trial. Lee, Mozer & Vecera (2009) asked whether priming of pop-out was due to the momentary storage of the target color's representation in Visual Short-Term Memory (VSTM) from one trial to the next. They loaded VSTM with four colored items and reasoned that if PoP is dependent on VSTM retaining target color information, then over-loading VSTM with these colors should wipe out PoP. Across four experiments, they consistently found that VSTM load was unrelated to PoP. Across three experiments, here we examined whether PoP is dependent on spatial VSTM resources, inspired by the findings that serial search is not affected by feature- but only spatial-VSTM load (Woodman & Luck, 2004). In Experiment 1, we compared feature- and spatial-VSTM load. We replicated the results of Lee et al.: feature-VSTM load had no effect on PoP. However, PoP was significantly reduced under spatial-VSTM load. In Experiment 2, we manipulated the amount of load (1 vs. 4 in feature-VSTM; 2 vs. 4 in Spatial-VSTM). Feature load had no effect on PoP. In contrast, the magnitude of PoP decreased with increased spatial load. In Experiment 3, we varied set size (3 vs. 12) in the PoP task: RTs decreased with larger set size and PoP decreased in magnitude. Importantly, the effect of set size did not interact with the effect of spatial-VSTM load in PoP. The results suggest that the degree to which a pop-out stimulus can direct attention unto itself is critically dependent on availability of resources in spatial VSTM, challenging current theories of parallel search and attentional guidance.

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56.309 **Novel Color Stimuli for Studying Spatial Attention**

James Herman[1](hermanj@gmail.com), Amarender Bogadhi[1], Rich Krauzlis[1]; [1]Laboratory of Sensorimotor Research, National Eye Institute, National Institutes of Health

The effects of covert spatial attention on color processing are not well known. Although feature-based attention to color is known to improve discrimination performance, no studies (we know of) have examined the effects of spatial cueing on color processing. Here, we report results using a novel color stimulus that incorporates many of the desirable features found in visual motion stimuli commonly used in spatial attention tasks. The stimuli were circular patches (3.23° radius) comprised of ~660 squares, each with a color randomly drawn from a Gaussian distribution along one axis of DKL space, plus a randomly chosen luminance increment or decrement. Similar to dot-motion stimuli, each square was reborn after a fixed "lifetime" with a new color and luminance. By varying the mean and standard deviation of the Gaussian distribution, we defined stimuli that differed from one another in discriminability. We used these stimuli in a spatial attention task. In the main experiment, human subjects were shown 4 patches (1 in each quadrant at 8° eccentricity) while maintaining central fixation, and the mean color in one of the patches changed during the trial. The task was to report the "direction" of the color change (2AFC). In 50% of trials (cued block), a pre-stimulus cue indicated (100% valid) the location of the impending change; otherwise, the change could occur at any of the 4 patches (uncued block). In a control experiment, subjects performed the same 2AFC task with a single patch. Results from 3 subjects show that thresholds in the cued block were significantly lower than those in the uncued block, and nearly identical to those in the single-patch control. These results demonstrate that spatial cues can selectively enhance the processing of color stimuli, and illustrate the usefulness of these novel stimuli for studying spatial attention to color.

56.310 **Involuntary Inhibition of Motor Responses Contingent on Top-Down Goals** Charles Folk[1](charles.folk@villanova.edu), Brian Anderson[2]; [1]Department of Psychology, Villanova University, [2]Department of Psychology, Johns Hopkins University

Effective motor control involves both the execution of appropriate responses and the inhibition of inappropriate responses that are evoked by response-associated stimuli. The inhibition of a motor response has traditionally been characterized as either a voluntary act of cognitive control or a low-level perceptual bias arising from processes such as inhibition of return and priming. Involuntary effects of top-down goals on motoric inhibition have been reported, but involve the perseveration of an inhibitory strategy. It is unknown whether the inhibition of a motor response can be selectively triggered by a goal-relevant stimulus, reflecting the automatic activation of a top-down inhibitory strategy. To explore this issue, we used a variant of the flankers task to determine whether irrelevant flankers that share a defining feature (a specific color) with a no-go target can selectively elicit motoric inhibition as revealed through a reverse compatibility effect. Participants were presented with centrally-presented targets that could be either red or blue, with red targets requiring the execution of a response (go targets) and blue targets requiring the withholding of a response (no-go targets). The targets were preceded by known-to-be irrelevant flankers that could be either compatible or incompatible with the upcoming target in their associated motor response, and they could be either the same color as the go target, the same color as the no-go target, or a different, neutral color (green). The results show that no-go color flankers selectively produce a reverse compatibility effect while the other color flankers are ignored, even when participants are given sufficient time to ignore the flankers and focus exclusively on identifying the target. The results thus demonstrate the involuntary inhibition of a motor response contingent on task goals, suggesting that goal-directed motoric inhibition can proceed in stimulus-driven fashion without the need for voluntary cognitive control.

56.311 **'Don't Look' Inhibition: Attentional and oculomotor inhibition at locations forbidden to saccades** Saurabh Dhawan[1,2](srdhawan@gmail.com), Donatas Jonikaitis[1], Heiner Deubel[1]; [1]Department Psychologie, Ludwig-Maximilians-Universität München, [2]Graduate School of Systemic Neurosciences, Ludwig-Maximilians-Universität München

Despite the behavioral and clinical importance of saccade inhibition, the cognitive processes underlying it have remained unclear. Using three different measures, we tested whether marking a location as forbidden to saccades ('don't look' location) involves suppression of perceptual and motor processes at that location. 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, when after a delay it reappears alongside a second cue. First, we measured the spatial allocation of attention during the delay through differences in visual discrimination performance and found that while marking a location as a future saccade target resulted in an attentional benefit at that location, marking it as forbidden to saccades led to an attentional cost. Second, saccade trajectories are known to deviate away from irrelevant distractors present close to the fixation-target path. We found that saccades curved away even more when the item being avoided was at the 'don't look' location as compared to any of the task-irrelevant locations thus suggesting greater inhibition of an explicitly forbidden location in oculomotor programming. Third, by randomly mixing catch trials (one in every four trials; only one target appears at response time) within blocks of match and nonmatch trials, we found that saccades to the catch stimuli at the location memorized as 'don't look' were slower than those at task-irrelevant locations. We believe this 'don't look' inhibition, elicited at locations that are forbidden to saccades, represents a novel example of inhibition in cognitive processes. It is spatially restricted and temporally persistent over long task durations, which is markedly different from 'inhibition of return' that can be detected at adjacent locations as well and dissipates automatically over long delays.

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56.312 **Object position biases in viewing and naming** Alasdair Clarke[1](a.clarke@ed.ac.uk); [1]School of Informatics, University of Edinburgh

Viewers display consistent attentional biases such as fixating the centre of the screen (Tatler 2007 JoV), or scanning a scene from left-to-right. Objects features are also known to contribute to attentional biases (e.g., Nuthmann & Henderson 2010 JoV); it is therefore likely that object position plays a role in such biases. In the present object naming study, we characterize the effect of object location on overt attention and object naming frequency, comparing how different representations of an object's location predict naming. 24 participants named as many objects as possible after previewing photographic images (100 in total) for 5 seconds. This data was transcribed and a list of object label for each scene generated. All objects corresponding to these labels were annotated, resulting in an average of 29 polygons per image, with on average 14 distinct object labels. To investigate the effect of position on attention we created "object maps" representing the distribution of fixated and named objects over our scenes. We find that the distribution of fixated objects can be fit by a distance metric x2 + ay2. Setting a = 1.8 gives us R2 = 0.87. However, this model fails to account well for the distribution of named objects, R2 = 0.35. With the introduction of a vertical bias, bx2+ ay2 + cy, the model successfully captures the distribution of named objects, R2 = 0.85. This result suggests that the position of an object has different effects on overt attention and on how interesting, or memorable, an object is: while there is a strong bias to fixate objects in the centre of the screen, the distribution of named objects is shifted towards the lower half of the image.

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56.313 **A Comparison of Covert and Overt Orienting of Social Attention** Ty W. Boyer[1](tboyer@georgiasouthern.edu), Bennett I. Bertenthal[2]; [1]Georgia Southern University, [2]Indiana University

Recent evidence reveals that observers automatically follow the direction of another's gaze. Here we tested whether a pointing finger automatically orients spatial attention in a similar manner. We used a spatial cueing paradigm where a central pointing hand or arrow preceded a peripheral target with an SOA of 100 or 600 ms. Participants responded to the direction of the target with either a manual (Experiment 1, N = 20) or an eye-movement response (Experiment 2, N = 20) measured with a Tobii 2150 eye tracker. Whereas the manual response task requires only a covert shift of attention, the saccade response task requires an overt shift of attention. In both experiments, participants were instructed that the stimulus cues were counterpredictive of the target location on 75% of the trials. The results from Experiments 1 and 2 revealed that responses in the 100 ms SOA trials were faster when the direction of either the hand or arrow pointing stimulus was congruent with the target location. By contrast, responses in the 600 ms SOA trials were faster when the target was incongruent with the stimulus cue. An analyses of the direction of the first saccade in the eye-movement task provided converging evidence that orienting responses were automatically cued by the pointing hand and arrow. It is also noteworthy that the percent errors in Experiment 1 were below 2%, but the percent errors in Experiment 2 were considerably higher (ranging from 8% to 16%). This difference between the errors occurring in the overt and covert tasks is substantial and suggests that it is more difficult to inhibit an eye movement than a keypress activated automatically in response to a social stimulus.

56.314 **Social and temporal orienting: Linked or independent?** Dana Hayward[1](dana.hayward@mail.mcgill.ca), Jelena Ristic[1]; [1]Psychology Department, McGill University

Spatial and temporal orienting are thought to constitute independent, parallel processes (e.g., Nobre, 2001). However, less is known about the relationship between social orienting, i.e., shifts of attention elicited by gaze direction to a particular location in space, and temporal orienting, i.e., shifts of attention elicited to particular moments in time. Namely, it is possible that temporal expectancy about when a target will occur might modulate spatial orienting elicited by a social gaze cue, thus questioning the proposed automaticity of social attention. To address this question, we presented participants with spatially uninformative gaze direction and temporally informative non-spatial cues, both in isolation and in conjunction, within the same task. Additionally, to determine whether the overall tonic alertness level of participants influenced either social or temporal orienting, half of all participants were assigned to the high alertness condition, where a response target was present on the majority of trials, while the other half were assigned to the low alertness condition, where a response target was present on fewer trials. Social orienting was resilient across all manipulations, emerging in its typical form regardless of whether gaze cues were presented in isolation, in competition with temporal cues or under changing levels of alertness. Temporal orienting proceeded in parallel with social orienting; however its effects emerged only when alertness was low. These data suggest that social and temporal orienting draw on different underlying attentional mechanisms. Social orienting appears to involve automatic processes while temporal orienting and alertness depend on executive, top-down processes.

Acknowledgement: NSERC

56.315 The effect of preterm birth and low birth weight on visual attention in adults

Adrian von Muhlenen[1](a.vonmuhlenen@warwick.ac.uk), Nicole Baumann[1], Dieter Wolke[1]; [1]Department of Psychology, University of Warwick

Preterm birth and low birth weight has been associated with an increased risk of cognitive, behavioral and psychiatric problems. In this study we examine how these problems are linked to specific attentional networks. Based on a sample from the Bavarian Longitudinal Study we compared a cohort of 121 survivors born very preterm (<32 weeks gestational age, GA) or very-low-birth-weight (VLBW <1500g) in 1985/86 (mean birth weight, 1323g; mean GA at birth, 30.3 weeks; 53% male) with 129 controls from the same population in Bavaria (mean birth weight, 3402g; mean GA at birth, 39.7 weeks; 47% male). Participants simply had to discriminate the orientation (left, right) of an arrow. The arrival of the arrow could be indicated by an alerting tone, its location (top, bottom) could be indicated by a spatial cue, and the arrow was always presented among other flanker arrows that were either congruent or incongruent. Each of these manipulation allowed to assess a separate component of attention: alerting, orienting and executive control (Fan et al., 2002, Journal of Cognitive Neuroscience). The RT index, representing efficiency for each attentional network (i.e., RT difference for tone present-absent, for cue valid-invalid, and for flanker congruent-incongruent) was calculated separately for each group. The VLBW group showed a large and highly significant deficit in the executive network and a smaller but significant deficit in the orienting network, but no deficit in the alerting network. Although RTs were generally longer for VLBW, the RT index result did not change when using RT ratio scores. Multiple regression analysis further showed that gender and IQ can to some degree – but not entirely account for this deficit in executive control. These results show that VLBW is linked to specific attentional deficiencies, especially those involving executive control.

56.316 Individual differences in the scope of spatial attention

Kristin E. Wilson[1](kristin.wilson@utoronto.ca), Justin Ruppel[1], Matthew Lowe[1], Mark Shaw[1], Rayan Kosnik[1], Jay Pratt[1], Susanne Ferber[1]; [1]Psychology, University of Toronto

Studies of spatial attention typically average effects across participants without considering individual differences in attentional scope. Individual differences in how attention is deployed and distributed may be associated with differences in visual working memory (VWM): individuals with smaller VWM capacity may attend to smaller regions of space. It is also possible that personality traits could be associated with attentional mode – e.g., individuals high in openness may show a broader scope. We explored the relationship between the spatial distribution of attention, VWM capacity and personality through Inhibition of Return (IOR), a well-studied phenomenon characterized by a reaction time (RT) cost for targets at cued locations relative to targets at uncued locations. Important for the present study, IOR spreads beyond the cued location as the inhibition decreases as a function of distance from the cue (Bennett & Pratt, 2001). Participants also completed a measure of personality and VWM capacity, with the hypothesis that the spatial distribution of IOR would differ between individuals. On each trial of the IOR task, the cue was centred in one of four quadrants on the screen, which was followed by a target, appearing at varying distances from the cue (invisible grid composed of 11 x 11 spatial locations). The spatial distribution of IOR was determined for each individual by calculating the slope of the regression line between cue-target distance and RT (negative slope indicates faster RT with increase in distance). A steeper negative slope suggests efficient release from IOR and a more localized/focal IOR, whereas a shallow negative slope suggests more diffuse IOR. Our results show personality and VWM predict the slope/distribution of IOR, providing evidence of individual differences in the spatial distribution of IOR, which may result from differences in the allocation of attention to the cue.

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Attention: Inattention, attention blindness

Tuesday, May 14, 2:45 - 6:45 pm

Poster Session, Royal Ballroom 6-8

56.317 Externalizing internal states with real-time neurofeedback to train visual attention

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When sustained for long periods of time, goal-directed attention eventually succumbs to distraction. We hypothesized that such lapses partly result from an inability to effectively monitor one's own internal state to detect impending failures — and that, if such states could be made more accessible, observers may learn to better predict and prevent lapses before they occur. Here we test this idea by externalizing attentional states with real-time fMRI during a sustained attention task. Observers viewed blocks of face/scene composite images. Before each block, they were cued to selectively attend to one category (e.g., scenes). For each trial, observers performed a go/no-go task in which they responded if the image was from one subcategory (e.g., outdoor scenes, 90% probability) but not another (e.g., indoor scenes, 10% probability). We measured behavioral performance in this task before and after an fMRI session to assess training effects. The fMRI session employed the same task, but observers received neurofeedback. This feedback derived from an online multivariate pattern classifier trained to detect whether attention was allocated to the correct category during each block. Feedback was delivered by altering the proportion of each category in the composite images. Namely, we externalized observers' attentional state by fading the to-be-attended category when the neural measure of attention declined and strengthened this category when it recovered. There was a general improvement in behavior from before to after training. Across participants, the amount of behavioral improvement was correlated with the amount of useful feedback that each participant received (where "useful feedback" was operationalized using a measure of oscillations in the image proportions). These results were not found in a yoked control group that received neurofeedback from the brains of different observers. Thus, real-time fMRI may enable more powerful and customized cognitive training, here enhancing attentional abilities after only one feedback session.

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56.318 Using Magic to Influence Choice in the Absence of Visual Awareness

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A common technique in magic is forcing, the influencing of participants' decisions in the absence of visual awareness. We investigated the strength of forcing in terms of five perceptual/cognitive characteristics (visibility, memorability, likability, and visual and verbal accessibility; Olson, Amlani, & Rensink, 2012) as well as personality measures such as locus of control (Duttweiler, 1984) and transliminality (the extent to which stimuli enter conscious awareness; Lange, Thalbourne, Houran, & Storm, 2000). Thirty-nine observers were each shown a sequence of 26 cards at a rate of 20–70 ms/card; one target card was shown for longer (150 ms). Observers were asked to freely choose a card and report it at the end of the trial. Each observer saw 28 trials in total. At the end of the experiment, observers were probed on whether they noticed that one card was shown the longest. Overall, personality measures predicted forcing, whereas the characteristics of the cards did not. Many observers (41%) did not notice the manipulation. This group chose the target card in 27% of the trials. Compared to those who did notice that one of the cards was shown the longest, they had a higher internal locus of control (89.1 versus 83.3) and spent less time using computers each day (5.2 versus 6.8 hours, all ps <.001). Degree of forcing was predicted by locus of control ($\beta1$ = -0.03, p = .009) and transliminality score ($\beta1$ = -0.10, p = .009). These findings confirm magicians' intuitions that some observers are more affected by unnoticed events, and are therefore more susceptible to magic tricks.

56.319 Brain oscillatory activity related to biologically relevant visual stimuli in a patient with affective blindsight.

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Tuesday PM

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Studies of cortical blindness have suggested that some residual visual function may persist despite the absence of perceptual consciousness. Here, a 60 year-old male patient (TN) with affective blindsight was tested to search for electrophysiological evidence of unconscious processing for biologically relevant stimuli (e.g. emotional faces and naked bodies). We carried out two different spatial attention-cueing experiments, in which we randomly presented facial expressions (fearful, happy and neutral) and female bodies (naked and dressed) as cues for 1000 ms, followed by an auditory target (500 Hz) to the right or left ear. TN was asked to respond to the auditory stimulus by pressing a button on the side of its appearance. We performed a 128-channel EEG recording and a time-frequency analysis using continuous wavelet transform, extracting all frequencies between 4 and 30Hz. We performed t-test analyses on cue-locked epochs of 4000 ms starting 1000 ms before cue onset, comparing positive vs. negative emotions as well as naked vs. dressed bodies. We found significant differences between fearful and happy faces over the right ventral frontal leads in the 7-8Hz range at 150-400 ms, and between happy and neutral as well as between fearful and neutral faces over the left ventral frontal electrodes in the 12-13Hz range, at 180 and 280 ms after cue onset. Finally, naked stimuli produced an event-related desynchronization (ERD) at 14-15Hz in the 140-180 ms period, as well as at 10-13Hz in the 740-840 ms period over centro-parietal areas. Our results suggest that emotional faces can be processed at a very early stage in the absence of awareness, producing significant effects in the low alpha band over right frontal channels with emotional valence, and modulating the high alpha band over left frontal electrodes with arousal. Alpha ERD thus appears to reflect unconscious perception of biologically relevant stimuli.

Acknowledgement: Supported by the Swiss National Science Foundation (grant no. 320030-125196)

56.320 The role of distractors' categorical distinctiveness in emotion-induced blindness

Briana L. Kennedy[1](b.kennedy@student.unsw.edu.au), Steven B. Most[1]; [1]University of New South Wales

In emotion-induced blindness (EIB) experiments, participants search for single targets within rapid serial visual presentation streams (Most, et al., 2005). Most targets appear some time after a distractor, which can be emotionally evocative or neutral. Operationally, EIB is defined as the greater target processing impairment following emotional distractors relative to neutral distractors. However, target processing in streams with neutral distractors is also often impaired relative to baseline. One possibility is that neutral distractors impair target processing due to their categorical distinctiveness within the stream (often a neutral picture of a person among pictures of landscapes). If so, can the impact of emotional distractors also be attributed simply to their categorical distinctiveness within the stream? In the present study, participants engaged in an EIB task under conditions that either minimized or maximized the categorical distinctiveness of the distractor. While the distractor was always categorically unique within each stream, such distinctiveness was minimized in a condition where the streams were composed of categorically heterogeneous items, and it was maximized in a condition where the streams were composed of categorically homogeneous items. Heterogeneous streams included pictures of different common objects (e.g., apple, piano, teapot), whereas homogeneous streams included pictures of a uniform object type (e.g., one stream entirely of teapots, one stream entirely of pianos, etc). Results revealed that in trials with neutral distractors, target accuracy was significantly impaired relative to baseline in homogeneous streams but was not significantly different from baseline in heterogeneous streams. In trials with emotionally evocative distractors, target processing was robustly impaired regardless of the distractors' categorical distinctiveness. These findings suggest that neutral distractors impair target processing when they are categorically distinct from other items in the stream, but that emotional distractors impair target processing even when this categorical distinctiveness is minimized.

Acknowledgement: NIH R03 MH091526

56.321 The Persistence of Inattentional Blindness and the Absence of Priming by Natural Scenes

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The question remains as to whether inattentional blindness (IB) persists for repeated presentations and whether scene gist can be processed without attention (Mack & Clarke, 2012). Using the Mack and Rock (1998) IB cross procedure, subjects were tested on 16 trials, 5 containing the same grayscale scene and 11 a mosaic pattern at fixation, along with a cross in the periphery. On every trial, subjects were asked to report the longer arm of the cross. After the 16th trial, which always contained a scene, subjects were asked whether they had been aware of anything other than the cross and the mosaic on any trial. 84% of the subjects were blind even though the scene appeared 5 times. A word stem completion task gave no evidence of semantic priming by scene gist and the critical scenes were not chosen significantly more or less than any others in a forced choice discrimination task. In a second experiment with 90 trials, 60 containing different grayscale scenes and 30 a grayscale mosaic, after reporting the longer arm of the cross, subjects reported as quickly as they could whether a string of letters appearing immediately after the cross and scene or mosaic was a word or non-word. The words were either related or unrelated to scene gist. Response time served as the measure of priming. After the last trial, subjects were asked whether they were aware of anything other than the cross and mosaic. 48% of the subjects reported never seeing the scenes. Significant lexical priming occurred only for subjects who reported seeing the scenes. Across both experiments, there was no evidence of encoding the scene gist of unseen scenes. These results show that IB persists with repeated exposure to foveally presented natural scenes.

56.322 Disruptions of spatial continuity increase awareness of scene properties

Lewis Baker[1](lewis.j.baker@vanderbilt.edu), Daniel Levin[1]; [1]Department of Psychology and Human Development, Peabody College, Vanderbilt University

This study tests how inconsistencies in spatial relationships affect visual property representations. We do this by violating a filmmaking heuristic known as the 180° rule, a convention of placing cameras in a consistent and limited area of the set. Violating this rule produces the percept of a sudden spatial dislocation or inconsistency. According to some theories of change detection, this disruption might mask awareness of other properties in a scene due to costs that arise from orienting to the new viewpoint and processing new spatial information. However, it is also possible that viewpoint inconsistencies increase visual awareness if the resulting reorientation prompts a new encoding of the scene. Two experiments investigated the effect of spatial discontinuity on visual awareness using change detection. In Experiment 1, participants viewed a single edited film that included a 180° violation, a property change, or both simultaneously. Property changes were significantly more likely to be detected when they co-occurred with a disruption of spatial continuity. In Experiment 2, violations were created not by moving the camera, but by rotating the orientation of actors in the scene, thus preserving consistent background information in violation and no-violation films. Again, more participants noticed the property change when it was presented simultaneously with a spatial discontinuity. Results suggest simple forms of spatial encoding support perceptual continuity. Additionally, the disruption of perceptual continuity may induce a general scene recoding resulting in increased awareness of visual properties.

Acknowledgement: NSF Award # 0826701 to DTL.

56.323 Voluntary disattention facilitates global motion detection

Miyuki G. Kamachi[1](miyuki@cc.kogakuin.ac.jp), Taichi Ishii[2], Isamu Motoyoshi[3]; [1]Faculty of Informatics, Kogakuin University, [2]Graduate School of Engineering, Kogakuin University, [3]NTT Communication Science Laboratories, NTT

There is a common belief in neuroscience that voluntary attention always facilitates sensory processing. A number of studies have shown that poor attention reduces neural responses and impairs behavioral performance to visual targets. In contrast to this classical view, we here show psychophysical evidence that voluntary attention to an irrelevant task improves, rather than impairs, detection sensitivity for global visual motion. Stimuli were a conventional random-dot pattern (RDP) in which a proportion of signal dots moved in a coherent direction (leftward / rightward) among noise dots of random directions, and a rapid serial stream of letters (RSVP) in the centre. Human observers were asked to detect coherent motion in the RDP with or without performing the concurrent letter identification task. Coherence thresholds (S/N ratio) were measured for RDPs of various densities, velocities, sizes, contrasts, and durations. We found that in most stimulus conditions, the coherence thresholds were lower when the observers were engaged in the secondary task than when they concentrated on motion detection. This paradoxical improvement in the performance disappeared when the RSVP stream was even more rapid so that the secondary task had a very high load. The subsequent experiments showed that the secondary task elevates, or does not affect, contrast and velocity thresholds for simple motion discrimination, and threshold for detecting spatial modulation of motion direction. The results suggest that voluntary withdrawal of attention can allow us to grasp overall structure of motion by enhancing spatial integration, and/or by suppressing spatial segregation, of low-level motion signals.

Acknowledgement: JSPS KAKENHI Grant Number 24530921

56.324 **Hiding a tree in a forest: Change camouflage as a mechanism for change blindness**

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An abrupt change in the direction of motion of a moving stimulus array induces change blindness for the simultaneous rotation of one element in that array (Yao, VSS 2012). Yet, a change in the direction of the array did not induce change blindness when one element changed color. We developed a "camouflage" theory that "like conceals like"—similar types of change to the array as a whole can conceal changes to an element of the array. A change in the direction of motion conceals a motion-based change (i.e., rotation), but not a color-based one. The camouflage hypothesis predicts that a change in color in the display should conceal a color-based change, but not a motion-based one. Participants completed a new change detection task in which they had to detect Gabor rotations or color changes amidst concentric arrays of grayscale circles. Simultaneous with the target change, the circles all changed in luminance—some increasing, some decreasing in order to minimize global luminance changes in the display. The local luminance changes effectively induced change blindness for the color changes, but not for rotations, lending support to the camouflage hypothesis. A non-target change in a display will conceal a target change insofar as the two are perceptually similar. Taken together, these findings provide a potential unifying mechanism for the variety of stimulus-based methods used to induce change blindness in the lab.

56.325 **Strategic games around the "centre of interest": Regulation of the dead zone of attention**

Yulia Stakina[1](staulia@mail.ru), Igor Utochkin[1]; [1]The National Research University "Higher School of Economics", Russia

The dead zone of attention (DZA) was previously found in change blindness research. DZA is a region closely surrounding the centre of interest (CI) where change blindness manifestations are exaggerated. Utochkin (2011) hypothesized that DZA partially consequences from a biologically predisposed search strategy that causes attention to avoid regions near the CI's as they appear to be uninformative. Here we attempted to test this hypothesis. We tried to influence the manifestations of DZA by manipulating this strategy. In order to test the hypothesis, we conducted three similar experiments consisting of two serial blocks. In Block I, observers were exposed to 12 flickering images inducing change blindness. Each image included a change within CI. Observers easily detected changes and subsequently couldn't ignore them. In Block II, images repeated and one marginal change (either near, or far from CI) was added to each previously found CI change. In Experiment 1, Block II was preceded by explicit informing observers about the essence of DZA phenomenon. In Experiment 2, there was no such information but all "near" and "far" changes were blocked to encourage implicit preference of corresponding locations. In Experiment 3, observers received both preliminary information and blocked trials. Results of all experiments were then compared to those reported by Utochkin (2011) in his experiment with the same stimulation but without informing observers and blocking trials. It was found that manipulating trials sequence reduced the search time across an image in Experiment 2. Manipulating information had no effect on search time around an image indicating relative constancy of global strategy. All manipulations reduced the number of missed changes within DZA suggesting local strategic regulation of attentional allocation around CI's. The effect was stronger in Experiments 1 and 3 than in Experiment 2 suggesting different contributions of explicit and implicit strategies.

Acknowledgement: The study is implemented within the Programme of basic research of the Higher School of Economics in 2012

56.326 **Why do drivers fail to see pedestrians and other vulnerable road users?**

Thomas Sanocki[1](sanocki@usf.edu), Mohammed Islam[1], Jonathan Doyon[1], Chanyoung Lee[2]; [1]Psychology, U. of South Florida, [2]Center for Urban Transportation Research, U. South Florida

In much of the world, fear of traffic crashes limits healthy and sustainable behaviors such as walking and biking. A possible root cause is based in perception: Drivers may sometimes fail to see pedestrians or bicyclists, increasing the probability that they will be crashed into. Here, we developed a method for directly measuring detection of vulnerable road users (VRUs: pedestrians, bicyclists, or motorcyclists). The results reveal a bias in perception that may be critical for understanding driver behavior. Methods. Observers detected VRUs from brief glances of largish street-scene pictures, presented (250 ms) left or right of fixation. The scenes were crowded (one or more autos present) or uncrowded (no autos). Crowding was expected to reduce accuracy of identification. Observers responded "yes" or "no" regarding the presence of a VRU, and received training with representative stimuli before testing. VRUs were present in 50% of the scenes, in appropriate (legal) locations. Results and Conclusions. Overall accuracy (percentage correct) was near 75%, and higher for uncrowded scenes than for crowded scenes. Critically, signal detection analyses indicated that the errors were not distributed equally; there was a bias for observers to miss VRUs, and a corresponding low false alarm rate. The bias occurred in both crowding conditions, but was stronger with crowded streets. The bias was consistent across observers (24 of 27). Further, the bias resulted in an especially high miss rate for pedestrians in crowded scenes — 65% of pedestrians were missed. The results indicate that fears of VRUs are well-founded. Drivers fail to detect VRUs, assuming that they are not present, especially when traffic is more congested. This may be an instance of the error of attention (Chabris & Simons, 2009) — "if I didn't see it, it wasn't there." This perceptual error can result in deaths in VRU crashes.

56.327 **Individual differences may reveal distinct mechanisms of attentional guidance**

Emma W. Dowd[1](emma.wudowd@duke.edu), Anastasia Kiyonaga[1], Tobias Egner[1], Stephen R. Mitroff[1]; [1]Department of Psychology & Neuroscience, Center for Cognitive Neuroscience, Duke University

The contents of working memory have been repeatedly found to guide the allocation of visual attention; for example, in a dual-task paradigm that combines working memory and visual search, an item active in working memory will be preferentially attended to during search (e.g., Soto, Heinke, Humphreys, & Blanco, 2005). There is much debate about whether such memory-based attentional guidance is automatic (Soto et al., 2005) or voluntary (Woodman & Luck, 2007). Generally, two distinct paradigms have been employed to assess memory-based guidance, one demonstrating that attention is uncontrollably captured by memory-matching stimuli (even at a cost to search performance), and one demonstrating that participants can strategically avoid memory-matching distractors to facilitate search performance. To examine why the different paradigms—which presumably tap into the same attentional mechanism—might support contrasting interpretations (automatic vs. voluntary), the current study utilized an individual differences approach: participants completed a battery of cognitive tasks that included an automatic attentional guidance paradigm (cf. Soto et al., 2005), a voluntary attentional guidance paradigm (cf. Woodman & Luck, 2007), as well as measures of visual working memory capacity and operation span. Participants exhibited varying levels of attentional guidance across both paradigms, allowing for meaningful individual differences assessments. Surprisingly, performance on the automatic guidance paradigm did not correlate with performance on the voluntary guidance paradigm, suggesting that these two paradigms—which have previously produced contrasting patterns of performance—may probe distinct mechanisms of attentional guidance. Furthermore, working memory capacity was more strongly predictive of performance in the automatic than the voluntary paradigm, suggesting that the automatic paradigm is more reliant on working memory capacity. The present results illustrate the utility of an individual differences approach for characterizing the processes linking working memory and visual attention.

Acknowledgement: Army Research Office (SRM), Dept. Homeland Security (SRM)

56.328 **Logical semantic operations in the absence of visual awareness**

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Accumulating evidence suggests that non-conscious cognition is extremely powerful. Brain-imaging studies have revealed extensive subliminal information processing in many different brain areas, from low-level perceptual regions, to regions in the parietal and temporal cortex, even up to "executive" areas at the highest level of the cortical and cognitive hierarchy, in the prefrontal cortex. Although great progress has been made in characterizing the flow of information triggered by unconscious visual stimuli in isolation, if and how multiple sources of unconscious information are integrated and combined is largely unexplored. I will present a series of behavioral and ERP studies in which we probed the possible flexibility and complexity at which multiple unconscious elements can be logically combined. Therefore, we designed a masked priming paradigm in which subjects were presented with a rapid stream of three words: an adverb ("not"/"very"),

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an adjective (e.g., "good"/"bad") and a target noun (e.g., "peace"/"murder"). The first two words could either be masked, or not masked. Subjects indicated whether the consciously presented target noun had a positive or negative valence. Crucially, the nature of the adverb dictated whether the overall three-word sequence was contextually consistent (e.g., very-bad-murder) or contextually inconsistent (e.g., not-bad-murder). Electrophysiological recordings revealed that such logical negation computations can partly unfold unconsciously, as reflected in similar effects for conscious and unconscious sequences on the N400 ERP component. However, at the same time qualitative neural differences between conscious and unconscious logical negation operations were observed on a the later P600 ERP component. Only conscious sequences elicited P600 effects, which were significantly stronger than the unconscious effects. These results suggest that some aspects of negation can unfold unconsciously, whereas others might not.

Color and light: Lightness and brightness

Tuesday, May 14, 2:45 - 6:45 pm

Poster Session, Orchid Ballroom

56.401 **Effect of Smooth Shape on Lightness Processing in Human Visual Cortex**

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Neurophysiological and neuroimaging studies have found localized retinotopic responses in low-level visual cortical areas to lightness change in the absence of changes in physical intensity. Lightness responses in human V1 have also been found to reflect perceptual grouping through occlusion (Boyaci et al., 2010), suggesting the involvement of non-local grouping mechanisms in low-level lightness processing. This led us to ask whether 3D shape could also influence lightness responses in low-level cortical areas. Knill and Kersten (1991) showed that the lightness difference in a version of the Craik-O'Brien stimulus largely diminishes when the luminance pattern is interpreted as shading variations due to surface curvature (Cylindrical), but not if it is interpreted as a combination of a flat surface and an abrupt change in two otherwise uniform reflectances (Rectangular). Our current study asked whether retinotopically localized cortical lightness responses would be reduced by contour cues consistent with the perceptual explanation of smoothly changing 3D surface orientation. We measured BOLD signals using fMRI at 3T from human visual cortex (n=6) in response to observation, with diverted attention, of Rectangular and Cylindrical variants of a Craik-O'Brien stimulus. We found an unexpectedly higher response to Cylindrical than Rectangular stimuli in localized, physically constant stimulus regions. Further analysis attributed this difference to confounding effects of stimulus geometry (distance from object contours) that, when controlled, indicated no significant difference in the response to the Cylindrical and Rectangular stimuli. Hence, our current measurements are consistent with a lack of influence of smooth shape cues on lightness responses in low-level visual cortex.

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56.402 **Humans correct contrast for defocus blur: a new kind of contrast constancy**

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Contrast constancy is the perceptual ability to perceive the contrast of targets in the environment as constant, even as sensory constraints reduce the contrast of the image transmitted up the optic nerve to the brain. Here, we demonstrate a new form of contrast constancy where humans correct for the contrast lost via defocus blur. We constructed a custom psychophysical rig capable of presenting light from three different distances simultaneously along the same line of sight. Subjects viewed stimuli monocularly through a 4mm artificial pupil using a bite bar. Each trial began with a focus target presented at 80cm. After the subject focused the target, standard and comparison targets—narrow bandwidth Gabors embedded in a hard-edged disks—were presented simultaneously for 200ms. A narrow band Gabor was used because defocus alters its contrast without altering its spatial wave form. The hard-edged disk provided a cue to defocus. The standard target had a Michelson contrast of 0.6 and was perfectly focused. The comparison target had variable contrast and was presented at defocus levels ranging from 0.00 to 0.75 diopters. In a 2AFC paradigm, subjects judged which of the two targets had greater contrast. If subjects exhibited no contrast constancy, they would match the targets' retinal contrasts. (Retinal contrasts can be predicted from the optical aberrations of each subject's eye.) If subjects were perfectly contrast constant, they would match the targets' on-screen contrast. We found that while subjects were not perfectly contrast constant, the defocus cues produced a significant increase in contrast constancy. Control conditions showed that subject responses were more strongly dictated by retinal contrast when cues to the target's defocus were removed. These results imply that defocus blur is used to correct contrast. These results demonstrate a new perceptual function for defocus blur, and demonstrate a new form of contrast constancy.

56.403 **Mach Bands: Contrast normalization?**

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Aim. Mach bands are the illusory bright and dark bars seen at the knees and feet of luminance trapezoids. The most popular account of Mach bands is that they result from a feature coding process that generates a sparse, binary representation of luminance discontinuities in terms of 'edges' and 'bars'. According to this account, the feet and knees of trapezoids elicit relatively strong responses in even-symmetric filters, and these are interpreted as indicative of bars. The filter responses to step-edges on the other hand are interpreted as indicative of edges not bars, predicting correctly no Mach bands at step-edges. Here I show through a modelling exercise that a simpler and more parsimonious explanation of Mach bands suffices that is in keeping with recent multi-scale filtering models of brightness coding: Mach bands result from contrast normalization. Method. One-dimensional representations of stimuli were convolved with a bank of one-dimensional, 2nd-Derivative-of-Gaussian filters that formed a complete basis set. Each convolution response was multiplied by 1/(1+kAs), where As is the amplitude response of each scale (s) of filter, and k is a factor that determines the amount of contrast normalization, set to unity for all filters and all stimuli. Filter responses were then summed to produce a predicted brightness profile. Results. Mach bands were observed in trapezoids, and Generalized Gaussian edges with exponents >1. Mach bands were not observed in step-edges, Hilbert-transformed trapezoids, trapezoids in which all phases were set to 90deg, and Generalized Gaussian edges with exponents <=1. All results are in line with psychophysical observation. Conclusion. Mach bands are caused by contrast normalization, not feature coding.

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56.404 **Blur and object layering in the barbell illusion**

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The "barbell illusion" (Shapiro, 2005) consists of a center bar flanked by a dark rectangle on one end and a light rectangle on the other. As the luminance of the bar modulates in time, a veil of shading appears to travel from one end of the bar to the other. The shading primarily moves in the direction of minimum contrast between the bar and the flanks; i.e., when the bar becomes white, the motion moves towards the light flank. Previous studies have shown that the direction of motion is predominantly controlled by the contrast at the thin (10 min) edge between bar and flank, but can also be influenced by larger-scale contrast; the effect is therefore useful for understanding the interaction of contrast at different spatial scales. Here we blur the contrast edges to understand how the removal of edge information affects the direction of shading. To measure the perceived direction of motion, a dot is placed just below the center bar and oscillates between the two flanks. The phase of the dot is fixed so that the dot is nearest the light flank when the center bar is at maximum luminance. The observers' task is report whether the shading motion is in or out of phase with the dot. When the bar is front of the flanks the motion is always towards minimum contrast, when the bar is in a layer behind the flank, motion is primarily perceived in the opposite direction. Haploscopic investigations (modulating bar in one eye, flanks in the other) find a reversal of direction on a substantial portion of trials. A motion energy model suggests the possibility of shading motion being determined at multiple spatial scales and it is possible that the strength motion signals may, in part, be determined by object depth plane.

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56.405 Why might black tetragons be more effective than white for inducing blanking? Jennifer E. Anderson[1](jander22@uic.edu), Michael W. Levine[1,2], J. Jason McAnany[1,3]; [1]Department of Psychology, University of Illinois at Chicago, [2]Laboratory of Integrative Neuroscience, University of Illinois at Chicago, [3]Department of Ophthalmology and Visual Sciences, University of Illinois at Chicago

A regular 2D array of four-sided figures (tetragons) placed on a neutral gray background forms a grid of alleys and intersections. Illusory smudges or scintillations can appear within the intersections (Hermann and Scintillating Grid, respectively). This pattern also increases thresholds for detection of targets placed within the intersections. Targets of the same polarity as the tetragons are only somewhat "obscured" by the tetragons. But if the targets and tetragons are of opposite polarity, the targets undergo a strong "blanking" effect (Extinction Illusion or Vanishing Disk). Curving the alleys increases tetragon complexity, and target detection becomes even more difficult. Overall, complex tetragons further obscure any targets, but only the effect of blanking is orientation dependent. Blanking is strongest when target and tetragons share similar orientations. Although obscuring occurs regardless of target and tetragon polarity, the blanking effect is weaker for white tetragons than for black tetragons. We test two possible reasons for this difference: (1) The contrast difference between alleys and tetragons might play a role in overall target detection; previous work did not account for the luminance of the alley gray. We changed alley grays covering a range of contrasts – yet black tetragons were always more effective than white at the same alley gray. (2) Superimposing white tetragons on an otherwise neutral-gray field creates a sharp increase in overall luminance between the display and response screen; superimposing black tetragons decreases luminance. We tested whether change in overall luminance was the important factor. To mitigate this abrupt temporal change, we made the luminance of the inter-trial response screen equal to the overall luminance of the test display. We found that change in luminance does not contribute to the weaker blanking effect of white tetragons. These results suggest that the effect may depend upon the asymmetry of ON and OFF systems.

56.406 Neural Correlates of Vasarely's Nested Squares and the Alternating Brightness Star Illusion in area V1 Jie Cui[1](jie@neuralcorrelate.com), Stephen Macknik[1], Xoana Troncoso[1,2], Jorge Otero-Millan[1], Susana Martinez-Conde[1]; [1]Barrow Neurological Institute, Phoenix, [2]Unite de Neuroscience, Information et Complexite, (CNRS-UNIC), UPR CNRS 3293, Gif-sur-Yvette, France

Vasarely's 'nested-squares' illusion shows that 90° corners are more salient perceptually than straight edges. On the basis of this illusion we developed previously the 'Alternating Brightness Star' illusion, which shows that sharp corners are more salient than shallow corners, and that the same corner can be perceived as either bright or dark depending on the polarity of the angle (i.e. whether concave or convex) (Troncoso, et al, 2005, 2009). Here we presented these illusions to awake monkeys while we recorded from single neurons in area V1, during guided-viewing conditions. Neuronal responses, calculated via eye-position corrected reverse correlation, concentrated on the illusory "folds" from luminance gradients composed of aligned corners, in agreement with previous psychophysical results. Sharp corners generated higher firing rates than shallow corners, irrespective of angle polarity, also consistent with human perception. These data support the hypothesis that corner and junction processing starts in the earliest neural stages of the visual hierarchy.
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56.407 Human lightness perception is guided by simple assumptions about reflectance and lighting Richard Murray[1](rfm@yorku.ca); [1]Department of Psychology and Centre for Vision Research, York University

Two successful approaches to understanding lightness perception that have developed along largely independent paths are anchoring theory and Bayesian theories. Anchoring theory is a set of rules that successfully predict lightness percepts under a wide range of conditions (Gilchrist, 2006). Some of these rules are difficult to motivate, e.g., larger surfaces tend to look lighter than small surfaces. Bayesian theories rely on probabilistic assumptions about lighting and surfaces, and model percepts as rational inferences from these assumptions combined with sensory data. Here I reconcile these two approaches by showing that many rules of anchoring theory follow from simple, realistic assumptions about lighting and reflectance. I describe a Bayesian theory that makes the following assumptions. (1) Reflectances follow a broad, asymmetric normal distribution that is skewed towards low reflectances. (2) Lighting consists of multiplicative and additive components (Adelson, 2000). (3) The proportion of additive light tends to be low. These assumptions predict the main rules of anchoring theory, including: (a) The highest luminance in a scene usually looks white (anchoring to white), and (b) other luminances have lightnesses that are approximately proportional to luminance. (c) A perceived reflectance range of less than 30:1 is adjusted towards 30:1 (scale normalization). (d) When a low-luminance region becomes larger, its lightness increases, and the lightness of all other regions also increases (area rule). (e) The luminance threshold for glow increases with patch size. (f) Lightness percepts do not change when all luminances in an image are multiplied by a common scale factor. (g) Lightness constancy is better in scenes containing many distinct luminance patches (articulation). Thus anchoring theory can be formulated naturally in a Bayesian framework, and many seemingly idiosyncratic properties of lightness perception emerge as rational consequences of simple, realistic assumptions about lighting and reflectance.
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56.408 Enhancement of simultaneous contrast with spatially uniform and spatially noisy transparent layers Erica Dixon[1](erica.dixon@american.edu), Arthur Shapiro[1]; [1]Department of Psychology and Center for Behavioral Neuroscience, American University, Washington D.C.

In simultaneous contrast demonstrations identical mid-luminance disks appear lighter and darker, respectively, when placed on black and white backgrounds. It has long been known that viewing the display through a transparent layer can heighten the strength of these demonstrations. There are currently two general types of models (not necessarily mutually exclusive) to explain why transparency strengthens contrast demonstrations: 1) transparency accentuates the perceptual interpretation of the layering structure of the image and 2) transparency lowers the light level, and multiplicative adaptation and spatial filtering highlights the perceptual difference between the patches. Here we investigate the effects of transparency by systematically varying both the transparency (alpha level) and the size of spatial noise within layers placed over simultaneous contrast displays. At each parametric level the observers set the luminance of side patches to match the test patches in the contrast display, thereby giving an estimation of the absolute perceived difference between the fields. We find that 1) regardless of spatial structure (i.e., ranging from no noise, to small-pixel noise, to large-pixel noise) the layers can increase the strength of the contrast demonstration compared to the non-transparency version and 2) the strength of the contrast difference depends on the noise structure of the transparency layer. Because the transparent layers are spatially contiguous with the contrast display, there is no way of perceiving that a transparent layer is present when the noise level is zero. It is particularly noteworthy therefore that the no-noise condition produces a large increase in the perceived difference between the disks; such a result cannot be due to changes in the perceived layering structure of the image and is likely due to the relative adaptation levels between the patches. We examine the changes that occur with spatial structure in terms of the Shapiro & Lu (2011) filter model.
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56.409 X-Junction Patterns Support Edge Classification Alan Gilchrist[1](alan@psychology.rutgers.edu), Stephen Ivory[1]; [1]Psychology Dept., Rutgers University, Newark Campus

Veridical lightness requires veridical classification of reflectance and illuminance edges. When edges intersect, the luminance values in the four quadrants produce two basic patterns: ratio-invariance and difference-invariance. Difference-invariance occurs when two illuminance edges intersect. Ratio-invariance occurs when one reflectance edge and one illuminance edge intersect (but it does not reveal which edge is which). In Experiment 1, observers looking through a beam splitter saw two identical bright squares: a square veiling luminance and a square hole in a transparent filter. Forced choice judgments were random when the background was homogeneous. A square wave background produced X-junctions that were ratio-invariant at the square hole but difference-invariant at the square veil. Forced choice judgments were correct 100% of the time. This shows that X-junction information is effective. In Experiment 2, a large square piece of black paper was suspended in midair (in a dimly-lit room) and illuminated by light from a slide projector (Gelb effect), causing it to look like white paper. Ratio-preserving X-junctions were created by overlapping two regions on it: a white paper disk and a rectangular shadow (produced by a small opaque rectangle mounted on the glass projector slide). This display was viewed by a group of 15 subjects, who matched the square background to a Munsell 8.7. Of these, 14 reported the rectangle as black paper (Munsell 2.4) and the disk as a spotlight. A separate group of 15 subjects who viewed the same display surrounded by a thick white border saw the square background as black (Munsell 2.5). Twelve reported the black rect-

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angle as a shadow and 11 reported the disk as white paper (Munsell 9.2). Overall, 25 subjects out of 30 reported an intersection of two kinds of edges, but the lightness of the large background determined which was which.
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56.410 **Koffka's invariance theorem, highest luminance anchoring, and the area rule apply to both lightness and perceived illumination**
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Helmholtz, Hering, and Katz all suggested that perceived illumination within a field is determined by average luminance. Zdravkovic et al. (2011) reported evidence that illumination is tied to highest luminance. In a series of experiments, we tested perceived illumination using a new technique. Looking into two square windows in the far wall of a vision tunnel, observers could see a patch of the far wall in each of two chambers. Each patch contained two shades of grey. They turned a knob to adjust the illumination level in one chamber to match that of the other, in effect creating the appearance of a single room with two windows. Lightness matches were taken using a Munsell chart. The stimuli placed in the chambers varied in luminance range, spatial frequency, and relative area. Illumination was matched for highest luminance, not average. Spatial frequency made no difference. Significant area effects were also found, both for perceived lightness and for perceived illumination, that is, the larger the area of the darker region in an aperture, the lighter and more dimly-illuminated it appeared, but only when the darker region had more than half of the area in an aperture, consistent with the area rule of anchoring theory. The area effects were complementary for lightness and perceived illumination, consistent with Koffka's invariance theorem. These results suggest that lightness and perceived illumination are complementary and both are anchored by the highest luminance, allowing an obvious expansion of anchoring theory to cover perceived illumination.
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56.411 **Lighting direction and visual field modulate the brightness of 3D objects**
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Background: When interpreting the shape of 3D surfaces the visual system assumes that illumination is mostly from above and slightly from the left. Visual search is parallel for below-lit targets amidst top-lit distractors, but not vice versa. However, visual search for oddly-illuminated singletons is serial when the 3D pose of cube targets and distractors is randomized. We asked whether the direction of lighting of randomly posed 3D cubes would influence their brightness (and/or perceived intensity of illumination). Method: An array of nine Lambertian cubes was stereoscopically rendered in low ambient illumination against a dark background. Individual cubes varied in their 3D pose, but all possessed identical triplets of visible faces. The cubes were illuminated from one of four directions: top-left (+60o elevation; -90o azimuth); top-right (+60o; +90o); bottom-left (-60o; -90o); and bottom-right (-60o; +90o). Illumination intensity (arbitrary units) ranged from 1-15 (linear steps). "Standard" cubes were illuminated from top-left at intensity 8; comparison cubes were illuminated from all four possible directions, and appeared in either the left or right visual fields. Using the method of adjustment (N=20, 13 male) we determined comparison cube illumination levels required to establish subjective equality with the standard cubes as a function of comparison cube visual field, illumination elevation, and illumination azimuth. Results: Cubes appeared significantly brighter in the left visual field (p=.008), and when illuminated from below (p<.001). There was a trend for right-lit cubes to appear brighter (p=.069). The enhanced brightness of surfaces lit from below was greatest when also lit from the right (p=.001). Conclusions: Surfaces lit from below appear brighter (more illuminated) than identical surfaces lit from above, due perhaps to long-term adaptation to downward lighting. This effect is modulated by azimuth, being strongest for illumination from the right. Brightness is amplified in the left visual field, presumably via attentional enhancement.
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56.412 **Effect of the apparent brightness of a space on lightness and saturation perception**
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It is known that color perception of an object is affected by its surround in each attribute, such as the simultaneous contrast effect on hue and lightness and the gamut expansion effect on saturation. Although the effects on a two-dimensional plane have been extensively investigated, those in a three-dimensional space are not well understood. It was reported that the lightness configuration of a room changes the apparent brightness of the space and affects the lightness perception of an object in the room. However, it is not clear if it would also affect to saturation perception. Here, we investigate how lightness and saturation perception are influenced by the brightness perception of surrounding environments. We examined the appearance of a color patch in the miniature room composed of achromatic colors, by color matching with a Munsell color chart. While the illuminance of the rooms was kept the same, the apparent brightness of the room was controlled by changing lightness configurations and surface materials. Five chromatic colors (5R5/6, 5Y5/6, 5G5/6, 5B5/6, 5P5/6) and N5 were used for test patches. We tested conditions with a two-dimensional plane for comparison. Each observer also evaluated the brightness of the rooms by magnitude estimation in a separate session. Results showed that the test patch in the room with low lightness appeared higher in chroma as well as in value, and vice vasa. On the other hand, the difference in the chroma perception of the test patch on planes with lower and higher lightness was smaller than those in the room. It was suggested that the difference in the overall brightness perception of the room affected lightness perception of patches, but did not change their apparent xy chromaticities, resulting in the change of saturation perception.
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56.413 **Figural organization determines the edge integration path in lightness**
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To maintain color constancy, our visual system must distinguish surface reflectance-based variations in wavelength and luminance from variations due to illumination. Edge integration theory proposes that this is accomplished by spatially integrating along an image path only those local oriented luminance and color contrasts that likely result from reflectance changes. The output of the edge integration process is a neural representation of relative reflectance across the visual scene. An anchoring rule — the largest reflectance in this representation appears white — maps the representation of relative reflectance onto an absolute lightness scale. Computations occur in this order: edge classification -> weight setting -> edge integration -> anchoring -> lightness. Lightness matching data from several studies using 2D displays are shown to be consistent with an edge integration model in which the visual system performs a weighted spatial summation of directed steps in luminance, where luminance is defined in log units. Three hypotheses are proposed regarding how weights are applied to steps. First, weights decline with distance from the surface whose lightness is being computed. Second, larger weights are given to steps whose dark sides point towards the surface. Third, edge integration is carried out along a path leading from a common background, or surround, to the surface. The last rule is needed to make the other two rules work in a self-consistent manner and implies an indispensable role for figural organization in any viable edge integration theory of lightness. The theory accounts for: simultaneous contrast; quantitative lightness judgments in disk-and-annulus, Gilchrist dome, and Gelb displays; and perceptual filling-in. I explain the motivation for the model and how it accounts both for 1/3 power-law lightness scaling of Gelb papers when the papers are surrounded by darkness and the veridical lightness scaling that occurs when the same papers are surrounded by a white frame (Cataliotti & Gilchrist, 1995).

56.414 **Effects of changes in atmosphere on lightness perception**
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The color of achromatic surfaces, i.e. their perceived reflectance, can only indirectly be inferred from the luminance image in the retina. Variations in illumination as well as different 'atmospheres' such as transparent media located between the object and our eyes may dramatically alter the luminance of one and the same object. Adelson (2000) proposed that in order to veridically perceive an object's reflectance regardless of the atmosphere through which it is seen, the visual system must invert, what he called atmospheric transfer functions (ATF), namely the functions which map reflectance to luminance values in different atmospheres. The inverted functions used by the visual system to infer lightness from luminance were called lightness transfer functions (LTF). To test twhether such an inversion adequately describes lightness perception, we measured ATFs and LTFs in checkerboards, which consisted of ten by ten checks with ten different, randomly assigned, surface reflectances. The checkerboards were rendered using Povray, and each of the ten different surface reflectances could be presented in one of a number of different 'atmospheres' including plain view, shadow, and different kinds of transparencies. The luminance range of the different reflectances spanned 16 to 398 cd/m2 in plain view. To measure the LTFs observers adjusted a comparison patch such that it appeared as light as one of the ten test reflectances viewed in different atmospheres. We find LTFs that are indeed almost perfectly inverse functions of the ATFs as indicated by a close correspondence between reflectance and perceived reflectance (lightness). The LTFs of our observers in different atmospheres are linear and differ by a multiplicative (slope) and a subtractive (intercept) factor. A shadow affects the slope whereas transparencies affect both the slope and intercept of the transfer function. The colour of the transparency affects the intercept while the translucency affects the slope.

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56.415 **Interaction of Ambient Lighting and LCD Display Polarity on Text Processing and Viewing Comfort**

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Liquid crystal displays (LCDs) present text by differentially twisting LCs to adjust the amount of backlight emitted to illuminate the characters. While LCDs provide ample luminance and contrast in most conditions, text quality deteriorates along with slower reading and increased viewing discomfort under dim lighting. The current study compared viewing comfort and performance under dim-to-normal lighting with different display polarity and size of visual field. 56 adults performed Threshold-Sized-Single-Letter Identification (TSSLI) and Normal-Sized-Word-Spelling-Check (NSWSC) tasks for 3 minutes each with 3 display polarity (positive/black-on-white, negative/white-on-black, black-on-grey), 2 (big, small) visual field and 5 lighting conditions (20, 44, 99, 220, 480 lux). Accuracy, speed, viewing distance, and viewing comfort were compared. Opposite performance pattern was observed between TSSLI and NSWSC. Accuracy and speed were better with positive polarity for TSSLI but better with negative polarity for NSWSC. Viewing distance was shorter with smaller visual-field and negative polarity, especially with TSSLI. With TSSLI, subjects reported blurry text and poor text contrast with negative polarity, but stronger glare with positive polarity in large visual-field, but no significant discomfort with NSWSC. The results suggest a significant interaction among ambient luminance, pupil size, and viewing discomfort. With TSSLI on positive polarity (a single small back letter on a huge white space), the bright background likely caused pupillary constriction, reduced peripheral optical aberration, and resulted in clearer retinal image for better identification (pinhole effect) but also induced stronger sense of glare. In contrast, negative polarity enlarged the pupil and caused blurry text. The vast dark background likely manifested specular reflection and reduced letter clarity. With NSWSC, however, text form was clearly visible regardless of display polarity but dark background was less stimulating and more comfortable for viewing. Overall, subjects preferred display that is less stimulating to the eyes (i.e., negative polarity and black text on gray).

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56.416 **Network Connections That Evolve to Contend With the Inverse Optics Problem**

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A fundamental problem in vision is understanding how useful perceptions and behaviors arise in the absence of direct information about the physical sources of retinal stimuli (the inverse optics problem). With respect to light intensity, psychophysical studies of lightness and brightness show that humans contend with this problem by generating percepts that accord with the cumulative probabilities of naturally occurring luminance patterns (Yang and Purves, 2004). To understand the neural mechanisms underlying this strategy, we examined the connections of simple neural networks with four neurons (a target sensor, a context sensor, an integrating neuron and a response neuron) and three synaptic connections between them. The networks were presented with patterns of adjacent luminance values drawn from natural scenes and evolved to respond to the luminance of the target sensor according to the cumulative probabilities of the stimuli experienced. The networks had no information about the physical sources underlying the stimuli; nor did they perform feature analysis or represent images. The evolved responses were similar to human psychophysical functions of lightness magnitude estimation and contrast, and the evolved connectivity to lateral inhibition observed in biological circuitry. The evolved excitatory connection from the target sensor allows the network to non-linearly scale its responses, whereas the inhibitory connection from the context sensor results in contrast effects. These observations imply that animal vision uses the same general strategy and mechanisms to contend with the inherent inability of light stimuli to specify physical parameters in the environment. Reference: Yang Z & Purves D (2004) The statistical structure of natural light patterns determines perceived light intensity. Proc Natl Acad Sci USA 101: 8745-8750.

56.417 **Accidental Cameras. Revealing the scene outside the picture.**

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There are many ways in which pictures are formed around us. The most efficient mechanisms are to use lenses or narrow apertures to focus light into a picture of what is in front. So a set of occluders (to form a pinhole camera) will let us see an image as we view a surface. For that case, an image is formed by intentionally building a camera. However, similar arrangements appear naturally by accidental arrangements of surfaces in the world. Often the observer is not aware of the faint images produced by those "accidental cameras" or they are misinterpreted as being shadows. Although pinhole cameras are the ones we are most familiar with, there are other types of arrangements that can be used to form images. An occluder blocks certain of the light rays, producing a diffuse shadow. In the cast shadow, there is more than just the silhouette of the occluder, there is also the negative image of the scene in front of the occluder. The occluder produces an anti-pinhole camera. If we were able to extract the light that is missing (that is the difference between when the object is absent from the scene and when the object is present) we would get an image. That image would be the negative of the shadow and it will correspond to the image produced by a pinhole camera with a pinhole with the shape of the occluder. Therefore, a shadow is not just a dark region around an object. A shadow is the negative picture of the environment around the object producing it. Understanding accidental cameras is important to explain illumination variations that would otherwise be incorrectly attributed to shadows. Understanding them is required for a complete understanding of the photometry of many images.

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56.418 **Early level receptive field properties emerge from artificial neurons evolved on the basis of accumulated visual experience with natural images**

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A fundamental issue in perception is how the visual system resolves the luminance inverse problem. A wholly empirical approach that contends with this problem, and rationalizes human lightness perception, is based on the cumulative probability of natural luminance patterns in human experience (Yang and Purves, 2004). The cumulative probability of natural luminance patterns is also an efficient way for biological neurons to encode environmental luminance patterns (Laughlin, 1981). What is not clear, however, is the visual circuitry necessary to resolve the inverse problem in wholly empirical terms. To address this issue we empirically evolved two-layer artificial neural networks to match the cumulative probability of naturally occurring 2-D luminance patterns. In the first layer, each of the network's 37 sensors received luminance intensity from a 0.12 deg2 portion of visual space. The outputs from the sensor neurons were forwarded via evolvable synaptic connections to a layer of integrating neurons. In the second layer, each integrating neuron projected the algebraic sum of the sensor neuron inputs to an output neuron via a further evolvable synaptic connection. Every synapse in the network was modeled as a sigmoidal transfer function, with its initial strength randomly initialized near zero. The artificial neurons evolved receptive fields that have a classical center-surround organization and automatic adaption to ambient light. They also show suppressive modulation, a neuronal property that has been used to explain a number of additional phenomena observed in experimental animals (Carandini, 2004; Bonin et al., 2005). These results suggest that biological visual circuitry uses a similar empirical strategy.

56.419 The effect of stimulus visibility on visual field inhomogeneities.

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Visual field inhomogeneities have been the subject of considerable investigation, but some aspects of these inhomogeneities, such as the vertical meridian asymmetry (VMA; Carrasco et al., 2001), are less well understood. The VMA is defined as particularly poor performance on the vertical meridian, directly above the point of regard. Cameron & Rathje (VSS 2006) hypothesized that the VMA depends on stimulus visibility. Here we test this hypothesis. Methods: Using Gabor patches of low (0.5 cpd) and relatively high (8.0 cpd) spatial frequency we concomitantly varied grating contrast and tilt (i.e., the higher the contrast the lower the tilt) in three 2AFC orientation tasks. Stimuli were presented at 1 of 8 locations around an imaginary circle at 4.5 deg. eccentricity and overall performance was about 80% correct. In a second experiment we briefly presented suprathreshold, real-world images to observers in a series of 2AFC categorization tasks (e.g., cat vs. dog) in the same manner as in the first experiment. We expected performance (measured by percent correct, PC) to be more homogeneous for high contrast stimuli. Data were fit with ellipses that were constrained by all but PC at the north location and we calculated visual field inhomogeneity in two ways: (1) the difference between the predicted PC based on the ellipse fit and the observed PC at the "north" location (the VMA) and (2) the ratio of the minor to major ellipse axis lengths, an index of the horizontal-vertical anisotropy (HVA, Carrasco et al., 2001). Results: Performance was homogeneous for real world images and the VMA (and HVA) became less pronounced as contrast increased for both Gabor stimuli. Conclusion: Target contrast/visibility may be a critical factor in the VMA. The lack of inhomogeneity for natural images supports the conclusion that the VMA is a low-level perceptual phenomenon.

Color and light: High level

Tuesday, May 14, 2:45 - 6:45 pm

Poster Session, Orchid Ballroom

56.420 Attention Filters for Colors: Isolating Single Colors

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Purpose: To measure how well humans can isolate a target color among heterogeneous distracter colors. Method: We used a centroid-estimation task to quantify this ability. For each subject, we first used a minimum motion paradigm to obtain 8 equiluminant lights evenly spaced around an ellipse in the space spanned by the (Stockman-Sharpe) cone fundamentals. This ellipse had an achromatic center, and the elliptically arrayed lights had the maximum saturation available on our monitor. Each subject was thoroughly trained with trial-by-trial feedback (showing the true centroid, the stimulus dots and the participant's response) to estimate the centroid of a cloud of dark dots on a gray background. In the color-selection task, on each trial, 3 dots of each color (24 in all) with locations drawn from a bivariate Gaussian distribution with a roved mean were shown for 300ms after an initial fixation period. The participant used a mouse-click to locate the centroid of the three target-color dots. Feedback was displayed following the response. Linear regression was used to derive the weights exerted by dots of different colors in the centroid computation used by participants. Results: Subjects weighted the target color substantially more than the distracter colors with ratio between the single-target color and the SUM of all distracter-color weights ranging from 2.5 to 4 on average. In control conditions, subjects performed the dot centroid task but the 8 colors were replaced with 8 achromatic contrasts that spanned the maximum range of the monitor. For all the target contrasts except the darkest, the ratio ranged from 0.3 to 1. Only the darkest contrast yielded performance comparable in effectiveness to that observed with each individual color. We conclude that subjects can effectively attend to single hues but not to single gray levels, with the exception of black.

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56.421 Remembering colors: Bias and variability

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Introduction: Remembering colors to match previously seen objects is a subjectively difficult experience. Memory is often blamed; however, real world memory tasks often require matching colors across changes in visual environment. Thus, such tasks require color constancy as well as memory. Are mistakes in such tasks caused by memory or failures of constancy? TASK: 120 observers matched the color of 16 real, painted cubes to a 1022 chip palette in 8 different conditions: (1) baseline, where matches were made adjacent to the palette; (2) across an illuminant shift; (3) cube embedded in an approximately color-opponent surround; (4) across a ten-minute memory delay (M); (5) – (8) each permutation of the above conditions. We compared the bias and variability of color matches in each condition. VARIABILITY: Compared to baseline, memory and illuminant conditions, but not the surround condition, showed significantly more variability. BIAS: Consistent with previous results, the illuminant change elicited a significant bias (imperfect constancy, ~80%) in the direction of the chromaticity of the illuminant. In contrast to flat, coplanar surfaces, embedding cubes in a surround elicited no significant biases (nearly perfect constancy). The empirical data on biases in color memory are contradictory: we found that memory was not biased towards greater saturation, nor towards prototypical hues, although memory matches showed small but significant biases in an apparently unsystematic way. This apparent memory bias (magnitude and variability between cubes) could be largely accounted for by modeling memory as unbiased but more variable than perception and taking into account the gamut and discretization of the matching palette. INTERACTIONS. When illumination, surround and memory were combined, neither variability nor bias were larger than with the illuminant shift alone. Conclusion: In a real world color memory task, errors could be largely attributed to failures of constancy, rather than failures of memory.

56.422 Focal colors as perceptual anchors of color categories

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With the aim to link color categorization to color perception we investigated whether the prototypes of color categories (focal colors) are more "colorful" than other colors. In this case, focal colors could work as perceptual anchors of color categories. We assessed "colorfulness" by estimating how many visible levels in saturation exist for the respective hue. For this purpose, we measured Just Noticeable Differences (JNDs) of saturation in CIELUV color space for hues of focal colors and of colors at the category boundary (boundary colors). We did so for all discriminable saturation levels available within the monitor gamut and extrapolated to the visual gamut. Then we counted how many JNDs fitted between the adaptation point and the visual gamut for each kind of hue. Our results for the yellow category show that focal yellow contains more discriminable levels of saturation than yellow-green, but similar amounts as yellow-orange. According to these results, focal yellow is not particularly "colorful". However, focal yellow yielded lower Weber fractions, and contained a higher number of discriminable colors when determining the upper limits of saturation by a maximally large circle in CIELUV space instead of the visual gamut. These results might indicate a particularly high sensitivity for focal yellow. However, in contrast to those for the visual gamut they depend on the color space in which equal saturation is defined. Hence, they might also be due to an inhomogeneity of CIELUV space that coincides with focal yellow. Measurements for other color categories will decide whether this pattern is characteristic for a particular sensitivity of focal colors or not.

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56.423 Numbering by color: the perception of summary statistics in color distributions

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The visual system can reliably extract the average value of stimulus distributions that vary along many dimensions, from orientation to facial expressions. We examined how sensitive observers were to the average chromaticity of color distributions. This average has special significance for color coding (e.g. to estimate the illuminant) but how it might depend on the level of representation (e.g. perceptual vs. cone-opponent) or nonlinearities (e.g. categorical coding) is unknown. Stimuli were 11 by 11 arrays of 0.75-deg spots that alternated between 2 component colors differing in hue or contrast. In one task, observers set the mean to a balanced blue-

See page 3 for Abstract Numbering System

green by adjusting the hue angle of bluish and greenish components. These settings were as reliable as blue-green boundaries in uniform color arrays, even when the components differed by up to 80 deg in the color space (~2.5 fold difference in S cone excitation). However, the two-color mean was biased toward blue, consistent with a compressive response to S cone signals. In a second task, observers instead adjusted the hue angle or contrast of one component until the two hues appeared opposite or complementary (a mean of gray). The chosen complementary hues did not clearly favor a specific (e.g. red vs. green or +LM vs. -LM) representation, and instead were characterized by high variability, far greater than for saturation matches between actual complements. These results for larger color differences suggest that color may not be perceptually represented in a space that assigns metrical relations among different color percepts.

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56.424 **Are Somali color categories fuzzy?** Delwin Lindsey[1](lindsey.43@osu.edu), Angela Brown[2]; [1]Department of Psychology, Ohio State University, Mansfield, [2]College of Optometry, Ohio State University, Columbus

To speakers of English, color categories are not disjoint, but rather overlap to some extent in color space. For example, some colors are blue, some are green, and some are both blue and green. The basis for these "fuzzy" categories is thought to be the color-opponent red/green and blue/yellow dimensions of color space. In this example, blue and green colors each produce a signal in the corresponding hue dimension, while blue-green colors simultaneously excite both hue dimensions. However, not everyone in the world speaks English, and there are many fewer named color categories in the Somali language than there are in English. For example, blues and greens fall into the same lexical category for many Somali informants, which some call "grue", but others call "gray", or "black". We therefore wondered what the Somali fuzzy categories are like. Methods: Twenty monolingual speakers of the standard dialect of the Somali language (ages 25–78, median=48 years) were allowed to use either one or two monolexemic color terms (CTs) to name each of 145 Munsell samples (20 hues at 7 lightnesses plus 5 achromatics). Results: Informants varied widely in how frequently they used two CTs (range: 4.8%--90.4% of samples, median=50.3%). When two CTs were used, they were generally one chromatic CT (which applied to a limited range of hues and lightnesses) plus one achromatic CT, apparently used as a modifier. Few samples (median=7.6%) were named with two chromatic CTs. These samples were named differently by different informants, and did not reliably fall near the boundaries predicted by the Hering primaries. Conclusion: Somali color naming does not readily reveal Somali fuzzy categories. Rather, in most of our Somali informants, it appears to be driven primarily by the salience of only one hue dimension at a time.

Acknowledgement: Supported by BCS-1152841

56.425 **Exploring the use of big data in color preference research** Casey McGlasson[1](cmcglass@indiana.edu), Jared Lorince[1], David J. Crandall[2], Peter M. Todd[1]; [1]Cognitive Science, Indiana University, [2]Informatics, Indiana University

The study of human color preferences, as well as the color preferences of other species, has long been an active area of research in psychology. However, these studies have been various in their methods and results. Researchers disagree about the ultimate and proximate causes of color preferences, as well as the ultimate and proximate causes of differences in color preference between groups, such as males and females. The purpose of this study is to evaluate the claim that sex differences in color preference exist using a novel implicit method, as well as to explore the possibility of functional, adaptive values associated with sex-specific color preferences. We propose a data-mining approach to studying color preferences using a dataset of more than 100 million photographs from Flickr, an online photo-sharing system. By analyzing the color spectra of photographs that specific populations of interest choose to upload, such as male and female users, we can assess color preferences in an implicit (behavior-based) rather than explicit (ratings-based) manner and on a much larger scale than can be done in a laboratory context or through survey techniques. Using this method, we find strong overall sex differences for the predominant reddish and bluish hues, with women uploading more photos with more reddish pixels and men uploading more photos with more bluish pixels. Finally, by contacting a self-organized community of 'color-blind photographers' on Flickr, we explore the relationship between sex-specific color preferences and sex-linked color vision defects (such as red-green color blindness).

56.426 **The functional effects of colour perception and colour imagery** Shuai Chang[1](shuai.chang@student.unsw.edu.au), David Lewis[1,2], Joel Pearson[1]; [1]School of Psychology, University of New South Wales, [2]School of Optometry and Vision Science, University of New South Wales

Functional brain imagining research and studies of brain-damaged patients suggest that colour perception and colour imagery have some overlap and independence in their neural mechanisms. Previous research into colour imagery has focused on compound images of both colour and form e.g. whole objects. Little is known regarding the characteristics of pure colour imagery, colour without form structure. The binocular rivalry method has been proved successful for measuring mental imagery objectively, quantitatively and reliably. Here we utilised the binocular rivalry technique to assess pure colour imagery. Experiment 1 consisted of three conditions, participants were asked to 1) imagine pure colours according to a letter cue. 2) imagine pure colours in the presence of background luminance. 3) passively view weak colour patches on the screen, prior to a binocular rivalry display of pure Gaussian colour patches, where one of the rivalry stimuli was always the colour that imagined or viewed. Results showed that dominance of binocular rivalry was significantly biased by colour imagery and perception; however, imagery trials in the presence of background luminance did not show the priming effect. In Experiment 2, we tested whether colour imagery was location-specific, i.e. whether it primed subsequent dominance in a binocular rivalry display presented at a different retinotopic location to the colour imagery. Colour imagery only primed subsequent rivalry when the imagery and rivalry occurred at the same retinotopic location. Our current study demonstrated that imagery of pure colour without form structure can have similar priming effects on subsequent rivalry displays as colour perception. In addition, the strength of this imagery bias effect was attenuated by concurrent uniform perception and was location specific. These results are consistent with previous studies of mental imagery using compound visual stimuli, demonstrating the potential to investigate mental imagery of different visual features.

56.427 **Violins are Green, Pianos are Blue: Cross-modal Sound-to-Sight Associations with Timbre in Synesthetes & Non-Synesthetes** William Griscom[1](wgriscom@berkeley.edu), Stephen Palmer[1]; [1]University of California, Berkeley

Previous research has shown that auditory-visual cross-modal associations for complex music in non-synesthetes appear to be mediated by the emotional connotations of the stimuli (Palmer & Schloss, in review), rather than (or in addition to) exhibiting a direct sensory correspondence, as has been found for more basic auditory features such as pitch or loudness (Marks, 1978). In this study, we investigated a class of musical stimuli of intermediate complexity: namely, instrumental timbres. In a series of experiments, participants indicated what colors, edge contrasts, and onset dynamics in visual displays "went best" with the sound of 17 different common musical instruments (e.g., violin, piano, marimba). We found evidence for emotional mediation in non-synesthetes' color choices, in that participants tended to choose colors whose emotional quality was similar to the rated emotional quality of the sound (e.g., "happy" looking colors, such as saturated red, were chosen for "happy" sounding instruments, such as a harpsichord). Systematic sound-to-sight correspondences were also evident for timbral attack and decay time in non-synesthetes' choices of "best fitting" edge contrasts (low to high spatial frequencies) and dynamic onsets (temporal dynamics of contrast) of circular shapes. In contrast, timbre-color synesthetes, who chose the colors most similar to the colors they experienced to the sounds, reported color experiences qualitatively different from those made by non-synesthetes. In particular synesthetes showed consistently weaker effects of emotional mediation and greater effects of low-level perceptual features. These results indicate that, although both groups give consistent patterns of responses, synesthetic color experiences to instrumental sounds appear to be driven more strongly by sensory-perceptual features and less strongly by semantic and emotional factors than is typical of non-synesthetic color associations to those same sounds.

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Binocular vision: Stereopsis

Tuesday, May 14, 2:45 - 6:45 pm

Poster Session, Orchid Ballroom

56.428 **Short-term visual memory for stereoscopically-defined depth** Adam Reeves[1](reeves@neu.edu), Quan Lei[1]; [1]Dept. of psychology, 125 NI, Northeastern University, Boston MA

Subjects saw a brief display of N numerals arrayed vertically below a continuously-present fixation target, each numeral in its own depth plane, and reported the numeral whose depth was that of an arrow shown at fixation. The arrow was either simultaneous with the display or followed the display after a variable ISI. Mean report accuracy (d') dropped rapidly from simultaneity to an ISI of ~200 ms, then recovered during the next second (but individual differences in baseline accuracy, rate of drop, and extent of recovery were notable.) These are novel phenomena; they suggest that depth information obeys both a rapid 'iconic' decay in short-term visual memory and a transfer from the initial display to a working memory that is only accessible much later on.

56.429 An evaluation system for stereopsis of beach volleyball players measuring perception time as a function of disparity within a virtual environment

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Purpose: To present a system for performance evaluation of stereopsis for beach volleyball players. Methods: Our dynamic stimulus consists of four equally rendered spheres with volleyball textures each rotating around its x-axis presented on a polarized 32'' 3D-TV (1920x1080p) at a distance of 5 m. All spheres have the same crossed disparity of 15 arcsecs and are placed in front of a shining sun background with zero disparity. In each iteration one of the spheres is randomly chosen to have an enlarged disparity by a disparity difference. The subject's task is to identify this sphere appearing closer as fast as possible by a button press while the detection time is automatically measured. Each disparity difference is evaluated in 16 iterations and classified as perceived with at least 10 correct decisions. Different lighting conditions are simulated by a lighting model enabling different intensities. In a preliminary example study we showed three disparity differences: 15, 45, and 75 arcsecs. They were presented in randomized order in two sessions. In session one light was set to highest intensity, in session two it was dimmed on the spheres. We measured 9 subjects with an age of 29.3 ± 2.3 years. Results: All subjects were able to perceive all stimuli except for two subjects under dimmed light conditions at the lowest disparity difference. The medians of the detection times vary between 892 and 3415 ms under full light conditions and between 958 and 4135 ms under dimmed light conditions. In both cases detection times increase for decreasing disparity differences and thus increasing difficulty. For dimmed conditions the detection times decrease compared to full light conditions where the differences vary between 1 and 1818 ms. Conclusion: We presented an evaluation system that reliably measures performance of stereopsis for beach volleyball players under simulated configurable realistic conditions.

Acknowledgement: Erlangen Graduate School in Advanced Optical Technologies (SAOT), University of Erlangen-Nuremberg

56.430 Estimating depth magnitude for flat, forced and reverse perspectives

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Objective: Assess perceived depth magnitude in stimuli with linear perspective cues that are congruent or incongruent with physical geometry. Further, determine whether perceived depth magnitude for bistable stimuli depends on percept (veridical versus illusory). Methods: Observers viewed three scaled-size versions (small, medium, large) of two 3D stimuli (forced-perspective, reverse-perspective) and one 2D (flat) stimulus. Stimuli contained painted cues: either congruent (proper) or incongruent (reverse and flat) with physical geometry. Reverse-perspectives were bistable (veridical or illusory); forced-perspectives and flat stimuli only afforded one percept. Observers' task: estimate perceived depth magnitude by physically adjusting distance between two rods. Results were compared to baseline depth estimations for two 3D stimuli (convex and concave) without painted cues. Results: Physical depth was overestimated for all sizes and types of stimuli, including baseline stimuli. However, overestimation decreased as stimulus size increased. For proper-perspectives and reverse-perspectives, estimated depths were roughly: 3.8 times the actual depth for small stimulus; 2.6 times for medium; 1.8 times for large. Surprisingly, estimated depths for the three flat stimuli, despite containing no actual depth, were roughly equal to those for the 3D stimuli of corresponding size. Depths had a trend – but not statistically significant – to appear larger for forced than for reverse perspectives stimuli. Further, estimates did not differ significantly for the reverse-perspective stimulus when perceived as veridical versus illusory. Depths for the non-painted baseline stimuli were about 1.5 times their actual depth. Conclusions: The large overestimation for smaller versus larger stimuli may be due to the smaller binocular disparity for the smaller stimuli, causing observers to rely more on linear perspective cues than disparity. The large depth estimates for the flat stimuli, combined with the small perceived depth differences for the three 3-D conditions point to a significantly larger role of painted perspective cues as compared to binocular disparity.

56.431 A novel stereoscopic display technique that minimizes perceptual artifacts

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Common stereoscopic displays use either temporal interlacing or spatial interlacing to present different images to the two eyes. The ones using temporal interlacing are prone to visible flicker, unsmooth motion appearance, and depth distortions; the depth distortions are changed in perceived depth as a function of the horizontal speed of the stimulus. Those using spatial interlacing—alternating pixel rows to the two eyes—have reduced resolution. We propose a novel "hybrid" display protocol that combines the better properties of temporal and spatial interlacing. In the hybrid protocol, the left- and right-eye views are interlaced spatially, but the rows corresponding to each eye alternate every frame. We performed psychophysical experiments that measured perceptual artifacts and resolution with temporal and spatial interlacing, and with the hybrid protocol. We measured motion artifacts by presenting a moving stimulus on a dark background: we found the stimulus speed above which motion artifacts were perceived. We measured depth distortion by presenting moving objects and having observers adjust their disparity until they appeared to move in the plane of the display. We determined effective spatial resolution by measuring letter acuity with stereoscopic presentation. Motion artifacts and depth distortions were reduced with the hybrid protocol compared to temporal interlacing, and effective spatial resolution was improved compared to spatial interlacing. The results suggest that the hybrid display protocol combines the best qualities of both spatial and temporal interlacing and thereby provides a more realistic perceptual experience.

56.432 Binocular visual direction is displaced by the slant of surrounding surfaces

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Relative visual direction between objects in stereoscopic depth is basically determined by the oculocentric direction signals from the two eyes (Mansfield & Legge, 1996). Here we show that spatial context (slant about the horizontal axis of surfaces that surrounds stereoscopic objects) also affects visual judgment of the vertical relative direction between objects. The effect was examined in two experiments in which a stereoscopic half-image was presented to each of the eyes with liquid crystal shutter glasses. The images consisted of two horizontal bars and two random-dot rectangles. When fused, each bar was perceived inside each of the two random-dot rectangle surfaces that had the same horizontal disparity as the bar. The same amount of slant was introduced to both surfaces. In a first experiment, the slant of the surface was achieved by changing the height of an observer's head position relative to the monitor. In a second experiment, shear disparity was introduced instead of the change of head position to eliminate cyclovergence induced by gaze elevation. The method of adjustment was used to modify the vertical position of the bar (comparison stimulus) that had zero disparity so that it appeared to be vertically aligned with the other bar (standard stimulus) which had one of five horizontal disparities (-15 arcmin to +15 arcmin in 7.5 arcmin steps). Two experiments showed that 1) when the upper side of each of the two surfaces was farther than the lower side, the standard stimulus was displaced to a lower position as the disparity was increased, and 2) when the lower side of the surfaces was farther than the upper side, the vertical displacement effect was not observed. These results suggest that spatial context should be taken into account to predict the vertical relative direction between binocularly fused stimuli.

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56.433 Stereopsis depends on a matched interocular mean luminance

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Stereopsis depends on matched inputs from the two eyes. The role of contrast and spatial frequency have been well studied but we know little about the effects of a mismatch in mean luminance between the two eyes. If stereo depends on a matched luminance between the two eyes there are three possible reasons why. First, even though the physical contrast is

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unaltered, the neural contrast sensitivity will eventually change and this could result in reduced stereo via its contrast dependence. Second, mean luminance is known to be associated with a slower visual response and this could reduce stereo due to temporal asynchrony. Thirdly, optimal stereo may require a matched interocular mean luminance per se. We thus tested the effects of different neutral density (ND) filters in a disparity detection task using a spatially filtered and unfiltered fractal noise stimulus. We first determined whether the reduction in stereo with mean luminance reduction in one eye was spatial scale dependent. We then determined whether any reduction in stereo performance could be accounted by the expected luminance-dependent temporal asynchrony. The results suggest that stereo does depend on a match mean luminance in the two eyes, it is scale dependent with greater reduction occurring at the lowest scale and that while temporal asynchrony is a factor resulting from reducing the mean luminance, it is not the sole cause of the reduced stereo performance. We conclude that there is a mean luminance per se constraint to stereo matching. Supported by an NSERC grant (# 46528) to RFH

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56.434 Testing the horizontal-vertical stereo anisotropy with the power-spectrum model of visual masking

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Stereo vision has a well-known anisotropy: at low frequencies, horizontally-oriented sinusoidal depth corrugations are easier to detect than vertically-oriented corrugations (where both are defined by horizontal disparity). Serrano-Pedraza & Read (2010, Journal of Vision, 10(12)) suggested that this stereo anisotropy may arise because the stereo system uses multiple spatial-frequency disparity channels for detecting horizontally-oriented modulations, but only one for vertically-oriented modulations. In this work we tested this hypothesis using the power-spectrum model of visual masking (imported from audition and luminance studies) in order to examine whether there are one or several channels, and to measure the bandwidth of channels. In the first experiment (4 subjects), we used Bayesian adaptive staircases to measure disparity thresholds for horizontal and vertical sinusoids near the peak of the disparity sensitivity function (0.4c/deg), both in the presence of white noise with five different power levels, and in the presence of notched noise with 6 different bandwidths. The use of notched noise avoids off-frequency looking. The masking linear model fit our results assuming a channel centered on 0.4c/deg with bandwidths of 2.95 octaves for horizontal corrugations and 2.62 octaves for vertical corrugations. In our second experiment (8 subjects), we measured disparity thresholds for horizontal and vertical sinusoids of 0.1c/deg in the presence of band-pass noise centered on 0.4c/deg with a bandwidth of 0.5 octaves. This mask had no effect on the disparity threshold at 0.1c/deg, for either horizontal or vertical corrugations. We ran the power-spectrum model assuming two types of detection, single channel detection and multiple channel detection. The multiple-channel model fitted better for both horizontal and vertical corrugations. We conclude that, contradicting our earlier hypothesis, the human stereo system must contain (at least) two channels for detecting horizontally-oriented and vertically-oriented depth modulations and that the channels at 0.1 and 0.4c/deg must be operating almost totally independently.

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56.435 Combining occlusion and disparity information: a computational model of stereoscopic depth perception

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The three-dimensional structure of the world can be reconstructed using the differences, or binocular disparities, between the positions and appearance of the images of the same objects on the two retinae. Occlusion of one object by another gives rise to areas visible only in one eye, called monocular occlusions, for which binocular disparities cannot be computed. Nevertheless, monocular occlusions can be perceived at precise locations in depth and can even induce the perception of illusory occluding surfaces. Since a growing body of literature has shown that monocular occlusions are an integral part of stereoscopic depth perception, it is important that we understand the mechanisms of depth extraction from monocular occlusions. Psychophysical experiments suggest that the visual system is able to assign depth from monocularly occluded areas based on the constraints imposed by the viewing geometry. However, none of the existing models of stereopsis use viewing geometry as the primary mechanism for quantitative and qualitative depth extraction in occluded areas. Moreover, no model has been shown to recover depth and structure of illusory occluding surfaces induced by the presence of monocular regions. We propose a new model of depth perception from disparity and monocular occlusions in which monocularly occluded areas are detected explicitly and quantitative depth from occlusions is calculated based on occlusion geometry. The model represents several levels of processing in the visual cortex and includes complex interactions between disparity and monocular occlusion detectors. It successfully reconstructs depth in a large range of stimuli including random-dot stereograms, illusory occluder stimuli, da Vinci arrangements and natural images. Thus we demonstrate that a dedicated set of mechanisms for processing of monocular occlusions combined with classical disparity detectors can underpin a wide range of stereoscopic percepts.

Acknowledgement: NSERC

56.436 Does the loss of sensory fusion demarcate fine vs coarse processing?

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In recent experiments we have found that a coarse stereoscopic mechanism is available to support depth perception at large disparities in individuals with amblyopia (VSS 2012). These subjects all performed poorly on conventional tests of stereopsis, but were similar to controls when the stimuli were presented at very large disparities and appeared diplopic. While the data are suggestive of distinct underlying (fine and coarse) mechanisms which map onto 1st and 2nd –order disparity processing, further study is required to make this link. The experiments reported here use visually normal observers and stimuli with different interocular contrast ratios presented at a large range of disparities. The goal is to determine whether coarse processing is responsible for depth percepts under conditions where the stimuli are diplopic and/or poorly matched in the two eyes. Luminance patches with a diameter of 30 or 21 min were presented stereoscopically at five interocular contrast ratios ranging from 20:100 to 100:100. In Experiment 1 we assessed diplopia thresholds to categorize disparities as fine (fused) or coarse (diplopic). In Experiment 2 observers performed a depth discrimination task for disparities ranging from 3 to 72 min. Regardless of size, depth discrimination was unaffected by interocular contrast differences when the test disparities were outside Panum's fusional area. Within the fused range, performance declined gradually at each contrast ratio with steeper slopes corresponding to larger ratios. These data suggest that the disparity at which sensory fusion is lost may mark a boundary beyond which only coarse (2nd-order) disparity processing is available to support stereopsis.

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56.437 Stereoanomaly for crossed disparity in the upper visual field and uncrossed disparity in the lower visual field

Akiko Yasuoka[1](a.yasuoka@scu.ac.jp), Masahiro Ishii[1], Shuhei Matsuda[2]; [1]School of Design, Sapporo City University, [2]University of Toyama

One sees floors more frequently than ceilings, and looks up at vertical objects such as persons or walls more frequently than looks down at them. This is true especially for young children in the critical period of stereopsis. With these conditions objects in the upper visual field are farther than the fixation, and objects in the lower are nearer than it. It may be assumed that the stereoscopic system is more adept at processing uncrossed disparities in the upper and crossed in the lower. The current study examines depth perception in each visual field with crossed and uncrossed disparities. In the experiment, a fixation and a test target were presented for 0.8s on a stereoscope. The fixation was right in front of the observer and the test was on the median plane; the test appeared at upper or lower visual field with a crossed or uncrossed disparity. The eccentricity of the test target was 1.5, 3, or 6 degree. The given disparity was 0, 3.6, or 7.2 arcmin at 1.5 degree eccentricity, 0, 7.2 or 14.4 arcmin at 3 degree, and 0, 10.8, 14.4, or 21.6 arcmin at 6 degree. The task of the subject was to report the apparent depth of the test target: 3AFC from far, near, or zero. 33 subjects participated. 15 of these subjects gave no anomalous signs. Five indicated defection of uncrossed or crossed disparity detection (Richards, 1970). Two seemed to be stereoblind or depth-reversal (Gillam, 1967). The other 11 could not perceive depth from uncrossed disparities in the upper and/or crossed in the lower. These results support our expectation.

Acknowledgement: CREST, JST

3D Perception: Cue combination

Tuesday, May 14, 2:45 - 6:45 pm

Poster Session, Orchid Ballroom

56.438 **Depth percept from motion parallax by backward/forward head movements** Masahiro Ishii[1](m.ishii@scu.ac.jp), Minoru Fujii[2]; [1]Sapporo City University, [2]University of Toyama

Three experiments were conducted to examine depth percept from motion parallax by backward/forward head movements. Depth percept thresholds were measured for backward/forward and rightward/leftward head movements. For a given depth, the retinal motion is independent of the visual eccentricity for rightward/leftward movements. On the other hand it depends on the eccentricity for backward/forward movements; a larger eccentricity causes a larger retinal motion. The stimuli were vertically oriented cylindrical surfaces generated using the ray-tracing representation on a computer. The frontal plane of the cylinder was the image plane. They subtended about 77x62deg at 50cm viewing distance. In a darkroom, observers moved and viewed monocularly the stimuli. They were asked to report the apparent curvature: convex or concave. (1)Thresholds were measured using random-dot surfaces. No difference found between backward/forward and rightward/leftward head motion. (2)A change of viewpoint transforms the stimulus boundary on the screen, e.g., perspective, pincushion/barrel distortion. To eliminate the effect of boundary transformation, rectangular-cropped random-dot surfaces were presented. With rightward/leftward head movement, the thresholds of depth percept for cropped stimuli were equivalent to those for the uncropped stimuli. With backward/forward movement, depth percept from motion parallax was deficient even if the stimuli had a large curvature. This result suggests that the change in the stimulus shape on the retina has important role to evoke depth percept when the observer moves backward/forward. The visual system needs to extract depth information from expanding/contracting dot motion produced by backward/forward head movement. In addition, it needs to estimate depth from eccentricity depending information. It seems that the processing is complicated for the visual system. (3) To investigate the effect of boundary transformation, solid white-colored surfaces were presented. With backward/forward head movement, the subject could perceive depth even if the stimulus had a small curvature.

Acknowledgement: CREST, JST

56.439 **Perceived depth magnitude with a combination of motion parallax and binocular disparity cues** Mark Nawrot[1](mark.nawrot@ndsu.edu), Jessica Holmin[1], Keith Stroyan[2]; [1]Center for Visual and Cognitive Neuroscience, Department of Psychology, North Dakota State University, [2]Math Department, University of Iowa

With a multitude of visual depth cues available, the visual system must often combine different cues to generate a singular impression of depth. We investigated how motion parallax (MP) and binocular disparity (BD) cues are combined to generate a single perceived depth magnitude. Our previous work (Nawrot et al., 2011, VSS) showed that depth from MP could be quantified with the transducer-corrected motion/pursuit ratio where: dMP = dθr/ dαe * 0.031 f, where r= 0.417 and e = 0.193. Depth from BD (with small depth intervals) can be quantified with the distance-squared law (Cormack & Fox, 1985). The goal of this study was to determine whether a weighted linear combination of individual MP and BD cue magnitudes account for the perceived depth magnitude in the cue combination condition. Observers viewed random-dot stimuli through a mirror stereoscope that provided ocular separation for stereo stimuli and monocular viewing of the parallax stimuli. To determine the perceived depth magnitude of a translating MP stimulus, MP stimuli were compared to static stereo stimuli in a 2IFC procedure in which observers indicated greater depth magnitude. MP stimuli translated laterally generating pursuit (dα: 1.1- 3.3 d/s) while dots within the stimulus window translated laterally (peak dθ: 0.09 - 0.55 d/s). Stereo stimuli had a range of disparities (1.5 – 15 min). For each MP stimulus, a point of subjective equality (PSE) was estimated from the psychometric function, giving the amount of BD producing the equivalent magnitude of perceived depth. In the cue combination condition a fixed 6.2 min of congruent BD was added to the translating MP stimulus, and PSEs were again determined. The cue combination condition generated perceived depth magnitude greater than a linear combination of weighted MP and BD cues explains. This result suggests non-linearities in the combination of MP and BD cues (Johnson et al., 1994).

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56.440 **Functional Use of Monocular Depth Perception in the Low Resolution Limit** Armand R. Tanguay, Jr.[1](atanguay@usc.edu), Noelle R. B. Stiles[2], Ben P. McIntosh[3], Mark S. Humayun[4]; [1]Departments of Electrical Engineering, Biomedical Engineering, and Ophthalmology, University of Southern California, [2]Computation and Neural Systems Program, California Institute of Technology, [3]Department of Electrical Engineering, University of Southern California, [4]Departments of Ophthalmology and Biomedical Engineering, University of Southern California

Monocular depth cues can provide a vivid sense of depth through image structure (such as perspective and occlusion) or through differential changes with movement (such as motion parallax). The persistence of monocular depth perception in the low-resolution limit has implications for the utility of retinal prostheses that are implanted within only one eye. An image depth-rating task previously demonstrated a significant difference in depth perceived from pixellated and post-blurred as compared to pixellated static images with false depth cues (N=11). In this study, the degree to which image representation affects the performance of functional tasks is investigated. Furthermore, the potential role of foveation in improving the performance of such tasks at low-resolution with restricted field-of-view is also studied. Foveation may be critical to improving the functionality of retinal prostheses that currently use a head-mounted camera without eye-tracking capability. A functional reaching task with a head-mounted display (HMD) was used to determine monocular depth perception capabilities at low resolution with different image representations. Images were acquired from a head-mounted wide-field-of-view camera, processed to low resolution (pixellation and blur or pixellation alone), and then displayed in real time in front of the subject's eyes. In the eye-pointed mode, the subject's gaze directed the subregion of the wide-field-of-view image displayed to the user; head position alone determined the subregion of the image displayed in the head-pointed mode. Subjects (N=3) were able to reach and grasp a bottle while avoiding obstacles faster with pixellated and blurred than pixellated representations. The task was completed faster when foveation was used to position the camera view. Experimental results demonstrate that monocular depth perception at low resolutions is useful in functional tasks. Results also show that appropriate presentation of images, as well as the implementation of foveation in retinal prostheses, will improve the efficiency of depth task performance.

Acknowledgement: National Science Foundation, National Science Foundation Graduate Research Fellowship

56.441 **Isaac Newton assists, Michael Jordan jams – training of perceived distance anisotropy** Oliver Toskovic[1](otoskovi@f.bg.ac.rs); [1]University of Belgrade, Department of Psychology

Perceived distance is anisotropic in such a way that perceived distances towards horizon are perceived as shorter than perceived distances towards zenith. Since this anisotropy is affected by proprioceptive and vestibular information, we assumed that it might be the consequence of gravity integration into perceptual-action schemes. Since, for example, reaching for something upwards opposes gravity, increasing of perceived distance in that direction helps, because it suggests that more effort is needed and therefore action is performed more easily. This assumption leads us towards the question what happens with anisotropy in sportsmen whose movements must be precise in various directions. Aim of this research was to compare perceived distance anisotropy between participants who train or who do not train sport in which eye-hand coordination is demanded on various directions. Experiment was performed on two groups of 30 participants in total, 15 out of which actively train basketball. Participants matched egocentric distances of two stimuli in a dark, on horizontal and vertical directions. Stimuli were dim lights, 6*4cm in size, placed on three standard distances 1m, 3m and 4m. Results show that there is a significant interaction between viewing direction and distance (anisotropy appears only on further distances) and between viewing direction and participant group (anisotropy is larger in a group which trains basketball). Based on this result, we can say that, when precise action is demanded, anisotropy increases, meaning that larger anisotropy might lead to more precise action. This finding is in line with our hypothesis on gravity integration into perceptual-action schemes.

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56.442 **Integration of stereo and texture slant cues measured with a slant estimation task** Zhongting Chen[1](u3001782@hku.hk), Jeffrey Saunders[1]; [1]Department of Psychology, University of Hong Kong, Hong Kong

Multiple sources of information are typically available for perception of 3D slant, such as stereo and texture. The relative contributions of different cues have been measured using a cue conflict paradigm. Some studies have found that stereo and texture contribute to perceived slant in a statistically optimal manner (e.g., Knill & Saunders, 2003; Hillis et al 2004). Todd, Christensen, and Guckes (2010) recently criticized the discrimination task used in previous studies. Todd et al used an estimation task to assess the perceived slant of cue conflict stimuli and observed no significant contribution from texture when stereo information was available. The goal of the present study was to investigate the perceptual weighting of stereo and texture cues using a slant estimation task. Stimuli were binocular views of a textured surface slanted in depth around a horizontal axis. The slant information provided by texture was manipulated by varying slant (0°-60°) and texture type (noise vs Voronoi). Observers indicated perceived slant by adjusting a 2D probe figure. Slant estimates showed large deviations from veridical, which varied across individuals, but tended to be systematic functions of actual slant. A subset of trials had conflicting cues: the slant specified by texture differed from the slant specified by stereo by ±15°. The relative weighting of texture and stereo information was inferred by comparing slant estimates in cue conflict and cue consistent conditions. We found that the Voronoi texture significantly influenced slant estimates, and the weighting of texture increased with slant. Our results are qualitatively consistent with those of previous studies using a discrimination task, suggesting that evidence for optimal integration of slant cues is not an artifact of methodology.

Acknowledgement: Supported by Hong Kong Research Grants Council, GRF HKU-752010H

56.443 The Interaction of Changing Disparity and Interocular Velocity Difference in Motion in Depth Perception

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There are two sources of binocular information that contribute to the perception of binocular motion in depth (Rashbass & Westheimer, 1961). One source of information consists of the rate of changing disparity (CD) over time and the other consists of interocular velocity difference (IOVD). Recent research (Persinger & Ni, 2012) showed different response curves as a function of dot lifetime for CD displays and IOVD displays. The purpose of this study was to compare the stereomotion perception in CD and IOVD displays when observer's sensitivity was set at a comparable level between the two types of displays. In the current study, uncorrelated random dot stereograms (URDS) were used to present displays with IOVD information only, and dynamic correlated random dot stereograms (DRDS) were used to present displays with CD information only. Dot lifetimes were selected that produced similar sensitivities to the two types of stimuli. The interaction between DRDS and URDS displays was measured using a motion aftereffect (MAE) paradigm. Observers were examined in the pretest and posttest on their sensitivities to DRDS stimuli, between which they were adapted with URDS stimuli. The results showed a significant difference in sensitivity between the pretest and posttest, indicating the adaptation to URDS displays has a significant effect on the stereomotion perception in DRDS displays.

56.444 Individual Differences in the Development of Depth Cue Combination

Bauke van der Velde[1,2](Bauke.vandervelde@gmail.com), Tessa Dekker[2], Georgina Aisbitt[3], Marko Nardini[2]; [1]Cognitive Science Center Amsterdam, University of Amsterdam, The Netherlands, [2]Dept of Visual Neuroscience, UCL Institute of Ophthalmology, UK, [3]Dept of Experimental Psychology, University of Oxford, UK

Adults integrate multiple depth cues to reduce their discrimination thresholds. In children, however, integration of stereo and texture cues to slant remains immature until 12 years (Nardini et al, PNAS 2010). This suggests that the neural mechanisms underlying integration of depth cues (Ban et al, Nature Neuroscience 2012) are still developing in mid-childhood. Here we investigated whether reliable individual differences in depth-cue integration are present in the "transitional" period of 8 to 12 years. Such differences would allow us to investigate the changes in neural processing of visual information underlying the acquisition of mature cue integration. We tested 25 observers aged 8-12 years in two sessions. Children judged which surface, a 45° standard or a variable comparison, was the most slanted, based on texture, disparity or both. 75% discrimination thresholds were estimated using a Bayesian adaptive staircase based on 80 trials in each condition. Thresholds for all three conditions were strongly correlated across sessions (all $\rho > 0.6$, $p < 0.001$). To understand the structure of variability across observers, we entered all six thresholds (3 conditions x 2 sessions) into a principal component analysis (PCA). The first component (60% of variance) described variation in global ability, while the second (19% of variance) described variation in cue integration ability, i.e. in the difference between single-cue and combined-cue conditions. The correlations indicate that individual children at this age provide repeatable measures, while the PCA indicates that an important source of variability is in the degree to which they integrate depth cues. These results provide a basis for identifying subgroups of good and poor cue-integrators. In an ongoing follow-up study we are using fMRI and MVPA to relate these individual differences in behaviour to differences in the cortical representation of single vs. combined depth cues.

Acknowledgement: James S McDonnell Foundation

Attention: Temporal

Tuesday, May 14, 2:45 - 6:45 pm

Poster Session, Orchid Ballroom

56.445 Temporal order of attentional disengagement and reengagement investigated by steady-state visual evoked potentials and event-related potentials

Satoshi Shioiri[1,2](shioiri@riec.tohoku.ac.jp), Yoshiyuki Kashiwase[1], Nobutaka Omori[1], Kazumichi Matsumiya[1,2], Ichiro Kuriki[1,2]; [1]Graduate School of Information Sciences, Tohoku University, [2]Research Institute of Electrical Communication, Tohoku University

Hidden formatting deleted. Delete this text! line-height:150%;layout-grid-mode:char">[Purpose] An attention shift has been assumed to comprise three stages of neural processes: disengagement from the initially attended location, shift to a new destination, and reengagement on the new location. We developed a novel experimental paradigm to estimate the timings of attentional "disengagement" and "reengagement". Hidden formatting deleted. Delete this text! line-height:150%;layout-grid-mode:char">[Method] We recorded two EEG components. One was steady-state visual evoked potential (SSVEP) for two flickering stimuli at different frequencies, which were presented on the left and right of the center of the display. The other was event-related potential (ERP) to the target superimposed on a flickering stimulus. After a peripheral cue presented around either flickering stimulus, participants stayed their attention on the cued stimulus, or shifted attention toward the other stimulus. We estimated the time course of attentional disengagement from the difference between the SSVEPs or P300 of ERPs to the stimulus that was kept attended throughout the trial after cue presentation and those to the stimulus that was initially attended and then ignored. We also estimated the time course of attentional reengagement from the difference between the measures to the stimulus that was initially ignored and then attended and those to the stimulus that was never attended throughout the trial. Hidden formatting deleted. Delete this text! line-height:150%;layout-grid-mode:char">[Results] The SSVEP data showed that attention was reengaged to a new object earlier than it was disengaged from the initially attended object. However, the P300 showed that reengagement and disengagement started approximately at the same time. Hidden formatting deleted. Delete this text! line-height:150%;layout-grid-mode:char">[Discussion] The present results suggest that there are different processes to control attentional disengagement and reengagement.

56.446 Hybrid search meets the Attentional Blink: How does searching through memory influence blink magnitude?

Sage Boettcher[1](sboettcher@partners.org), Trafton Drew[1,2], Ashley Sherman[3], Jeremy Wolfe[1,2]; [1]Brigham and Women's Hospital, [2]Harvard Medical School, [3]Department of Psychology, Stony Brook University

Observers are able to search visual displays for multiple possible target objects, held in memory. In this so-called "Hybrid Search", reaction time increases with the log of the number of items held in memory (Wolfe 2012). What resources are consumed during the time required for the memory search? To investigate this question, we studied the effect that memory set size had on the Attentional Blink (AB) when identification of the first target (T1) required search of the memory set. In 3 experiments, observers memorized 2, 4, 8 or 16 items. In the subsequent AB experiment, the T1 task was to report the presence of a member of the memory set. In Experiment 1, the memory set and all members of the RSVP stream were letters. The T2 task was to identify a single red letter. In Experiment 2, the memory set and all members of the RSVP stream were objects. The T2 task was to judge which of four possible objects appeared in the red frame. We observed a significant interaction between AB magnitude and memory set size in both experiments: larger memory set size was associated with a greater deficit in reporting T2 at early lags. In Experiment 3, T1 was a memory set object that was embedded in a stream of numbers and a single red number served as T2. Unlike previous experiments, AB magnitude did not interact with memory set size. Taken together, our data suggest that the size of the memory set for T1 influences subsequent processing only when other items in the RSVP

See page 3 for Abstract Numbering System

stream are similar to the target item. Simply invoking a memory search with T1 is not enough to impair subsequent processing of visual items if those items are in a different category (e.g. an object in a stream of digits).

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56.447 Task demands modulate the late posterior N1, but not the C1 ERP components evoked by task-irrelevant information presented during the attentional blink

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The attentional blink (AB) is typically thought to represent attenuated post-perceptual processing of the second of two targets identified in an RSVP stream. However, recent fMRI evidence has demonstrated that BOLD responses in visual cortex, including V1, can be attenuated during the AB. While this evidence is consistent with the notion that earlier stages of processing are also attenuated during the AB, recent EEG evidence has shown that the striate cortex generated C1 ERP component is not attenuated during the AB (Jacoby et al. 2011). This EEG evidence suggests that the attenuated BOLD responses in V1 observed in the fMRI studies resulted from feedback from higher-order processing areas. These studies provide suggestive neural evidence that the AB may arise from perceptual failures as well as post-perceptual failures, but the precise impact of the AB on the earliest stages of neural processing remains unclear. To investigate this issue, we manipulated first target (T1) difficulty and used EEG to measure neural activity in response to a task-irrelevant probe present in upper or lower visual fields simultaneously with the centrally presented second target (T2). Analysis of the ERP data (n=11) confirmed that the C1 component evoked by the probe presentation at T2 was not suppressed during the AB when compared to outside the AB ($p>.05$) and it was not modulated by T1 difficulty ($p>.05$). However, mean ERP amplitude in the 220-240ms time range measured at occipital and parietal electrodes contralateral to the probe location was significantly reduced under increased T1 difficulty inside the AB, but not outside the AB ($p<.05$). These findings provide further evidence that V1 activity is not reduced during the AB, not is it modulated by increased attentional demands imposed by T1. However, the findings do suggest that T1 difficulty modulates activity evoked by task-irrelevant information presented during the AB.

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56.448 A daytime nap reduces the attentional blink

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The attentional blink (AB) is an impairment in detecting the second of two targets that appear in close temporal succession. Previous research suggests that the AB is reduced after days of practice (Maki & Padmanabhan, 1994), but not after four consecutive blocks in one session (Taatgen et al., 2009). Here we investigate the role of sleep in modulating practice-dependent changes in the AB. We used a rapid serial visual presentation (RSVP) display comprising a stream of 26 English letters presented at 12 items/s. Two of the letters were targets cued by an annulus, and the number of items between the first target (T1) and second target (T2) was varied to yield a lag of 2, 5 or 10 items. Participants reported which two letters they thought were circled, and no feedback was provided. Participants completed the task at 9am, 12pm, 3pm and 5pm for a total of four sessions in one day. At 1pm, half the participants took a polysomnographically recorded nap for 60-90min, while the other participants went about their normal day or sat in a room quietly resting. Pooling the non-napping groups, we observed a significant increase in correct T2 reporting across sessions only within the nap group, and only for lag 2. The magnitude of improvement correlated positively with proportion of light stage two sleep, and negatively with proportion of deeper slow-wave sleep. We estimated the efficacy, latency and precision of attentional selection using a mixture model that considered the serial position of non-target items mistakenly reported as T2. These analyses indicated that the improvement observed in the nap group was due to increased efficacy (probability of reporting a T2-relevant item), with no change in latency or precision. Our results suggest that sleep, particularly stage two sleep, improves temporal attention.

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56.449 Revisiting the spread of sparing in attentional blink: Attentional selection or resource limitation?

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The attentional blink (AB) refers to the deficit in reporting the second of two targets (T2) in a rapid serial visual presentation (RSVP) stream when this target is presented in less than 500 ms after the onset of the first one (T1). It is under debate whether the AB originates from a limitation of cognitive resources or a distractor-triggered attentional suppression. In this study, we put a distractor (Dinter) or an extra target (Tinter) between T1 and T2 while at the same time manipulated the time interval between Dinter (Tinter) and T2 (0, 200, 500 ms). The level of transient attentional enhancement induced by the detection of T1 was also manipulated by adding external noise to T1. Results showed that, compared with the dual-target condition, T2 performance was better in the consecutive-target condition when T2 was close in time (0 ms) to Tinter or Dinter (i.e., the spread of sparing), but was worse when the interval between T2 and the preceding item was longer. Adding external noise to T1 improved T2 performance when T2 was close in time to the preceding item, irrespective of whether this item was Dinter or Tinter. These findings are better interpreted with an extended resource account according to which AB occurs due to the limitation of attentional resources but a chunking process can be utilized to improve target performance.

56.450 Individual Differences Within and Across Attentional Blink Tasks Revisited

Gillian Dale[1](gd03fh@brocku.ca), Paul E. Dux[2], Karen M. Arnell[1]; [1]Department of Psychology, Brock University, [2]School of Psychology, The University of Queensland

When the second of two targets (T2) is presented in close temporal proximity (within 200-500 ms) to the first (T1), accuracy for reporting T2 is reduced relative to when the targets are separated by longer durations--the attentional blink (AB). Two recent studies have shown that individual differences in the magnitude of the AB are stable both within a single testing session and over time. While one study found a large positive correlation between AB magnitude when there was an attentional set/task switch between T1 and T2 and when there was not, the other study found no relationship between switch and no-switch paradigms. The current study was conducted to clarify this discrepancy by examining the reliability of, and relationships among, individual differences in AB performance on 5 different versions of the standard dual-target RSVP paradigm (three of which involved an attentional set/task switch between T1 and T2, and two of which did not). Participants completed all 5 paradigms, and then returned 7-10 days later to again complete the same paradigms. All 5 versions were reliable both within, and across, testing sessions, demonstrating again that individual differences in AB performance are stable over time. In addition, all 5 AB versions were significantly intercorrelated, although the strength of the relationship differed depending on the extent to which the T1 and T2 attentional sets/tasks overlapped. These findings provide evidence that multiple distinct dual-target RSVP tasks do share underlying variability, providing support for the use of different versions of the paradigm in the literature.

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56.451 An attentional blink for moving stimuli and for tasks combining form and motion perception

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Attentive processing of a target stimulus (T1) embedded in a sequence of serially and rapidly presented distractor stimuli results in a transient impairment of detecting a second, subsequently presented target stimulus (T2). This impairment is known as the attentional blink. In the majority of previous studies of this phenomenon T1 and T2 were stationary visual stimuli. Considering the two cortical processing pathways for form and motion, we explored whether an attentional blink also occurs for stimuli and tasks relying on the dorsal visual pathway. In addition, we examined how processing along one pathway affects processing along the other. We conducted four experiments using moving random dot patterns and stationary letter stimuli and tested each possible combination of motion and letter as T1 and T2. Subjects had to either only detect T2 (single task) or had to identify T1 and detect T2 (dual task). We found a pronounced impairment in detecting T2 after identification of T1 for all combinations, which lasted for approximately 300ms. The point of maximum impairment differed between conditions and occurred around 100-300ms after presentation onset of T1. Subjects usually missed more than one third of T2 stimuli presented at that point in time in the sequence. Our results document an attentional blink for motion processing and support the hypothesis that it reflects a global attentional effect that is not restricted to one of the two processing pathways in the visual cortex.

56.452 A cause for non-Granger causality

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Identifying causal interactions in neural ensembles is, generally, a challenging task when multiple variables, causal loops, self-interactions, and strong nonlinearities are present. The Granger causality (GC) along with its multivariate and nonlinear descendants recently gained popularity. GC paradigm is based on removing one variable at a time from the ensemble and estimating how this affects predictability of the remaining variables. This approach cannot be used to evaluate self-interactions and, besides, has a strong tendency to weaken causality estimates when applied to non-separable systems (both linear and nonlinear), where a variable's information is not completely removed by simply removing the variable. For example, consider a variable A, which causally influences variables B and C, A->C having a longer time lag. A->C causality will be underestimated by GC-based measures compared to A->B causality because A's information is encoded in B even with A eliminated. Here a non-GC approach, which avoids such artifacts, is proposed. The variable tested for causality is never removed from the ensemble, its causal input is estimated from the full ensemble predictions instead. Based on this approach two new causality measures are proposed, one (linear) based on multivariate autoregressive fit (CARMA), the other (nonlinear) based on higher-order mutual information estimates (CIM). The measures were tested on various simulated and biological/neural datasets and compared favorably with GC-based measures. When applied to visually evoked potentials CARMA and CIM produced similar results, hence validating them given the very different methods. Strong causal interactions were observed between occipital (OP) and lateral-occipital (LO) scalp regions, when the stimulation (contrast reversal) was contralateral to the ROIs. For both measures the LO->OP causality peaked around 100 - 150 msec from the stimulus onset. CIM indicated ~5 msec time lag of the causal interaction, possibly, a feedback from the LOC/MT complex to early visual areas V1/V2/V3.

56.453 The time course of attention, cueing, and competition

Anna Wilschut[1](a.m.wilschut@vu.nl), Jan Theeuwes[1], Christian N.L. Olivers[1]; [1]VU University Amsterdam

Attention rapidly enhances perception at cued locations, but under some conditions this is followed by a decline in performance. We investigated which factors may underlie this attentional transience. In three studies a cue indicated with 100% validity the location of a masked target, which was presented at various SOAs. The first study demonstrated that the transient component can be observed when the cue and the target are presented invariably at central fixation. However, it was dependent on competition from distractors surrounding the target. This suggests that the transience is not due to spatial shifting but reflects the degree to which the cue protects the target from competition. The second study manipulated the properties of the cue and the target. The results showed that performance is initially determined by sensory interactions between the two stimuli, after which attention starts to dominate the response. Third, we investigated the basis of the competition effect by manipulating different distractor properties. The results, now obtained in a spatial cueing task, confirmed that the transience was due to distractor competition and not on spatial shifting. Performance was overall worse when the distractors were similar to the target, or when a single distractor competed for the response. However, the time course of the performance function was similar across the distractor conditions. These results show that the later decline in the cueing pattern can be caused by different phenomena known from the literature, such as crowding, grouping, or the flanker effect, as long as these pose enough competition for the target. In conclusion, we show how cueing enhances perception over time in the presence or absence of competition. The results are suggested to provide a basis for integrating a number of findings in the visual cognition literature.

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56.454 Electrophysiological signatures of temporal segregation and integration of visual information – an MEG study

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The balance between temporal segregation and integration of incoming sensory information constitutes a functional necessity of visual information processing. Whereas segregation establishes discrete temporal entities and therefore allows for an effective read-out of information at one particular instant, it is also critical to integrate and accumulate sensory input over time to preserve perceptual continuity. We operationalized temporal segregation and integration using a forward masking procedure with a variable stimulus onset asynchrony (SOA), while observers performed an enumeration task. Concurrently, we recorded electrophysiological brain activity using MEG in order to map the neuronal time course prior and in response to these two intrinsically temporal mechanisms. Enumeration is a particularly interesting task in this context, as it has previously been shown that its capacity critically depends upon the amount of temporal integration between two successive visual displays. The target items were physically identical to the mask elements and were presented superposed upon the masking pattern, such that an improvement in enumeration performance with increasing SOA indicated observers' ability to temporally segregate the onset of mask and target displays. Along these lines, we hypothesized that correct trials indicate temporal segregation, whereas incorrect trials are associated with temporal integration of mask and target information. In pre- and peri-stimulus intervals alpha-to-beta oscillatory power was higher in temporal integration trials. This effect originated from occipital and temporal generators. Temporal segregation evoked a stronger visual response time-locked to the masking pattern with a widespread, mostly left hemispheric occipito-parietal topography. Relating these two effects around (pre-, peri- and post) stimulus onset within a single-trial analysis reveals the electrophysiological circumstances under which visual operations create discrete temporal windows over which sensory information is accumulated.

56.455 Remapping Time Across Space

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Introduction: Prior evidence suggests that attention's temporal properties differ between the left and right visual fields (LVF and RVF). Notably, Verleger et al.'s (2008) N2pc (parietal contralateral) ERP potentials peaked ~30 msec earlier for LVF than for RVF targets on a bilateral-stream Rapid Serial Visual Presentation (RSVP) identification task. Might this hastened neural response render LVF targets perceptually available sooner than RVF targets? If so, how might the visual system reconcile these timing differences to estimate simultaneity across the LVF and RVF? Method: Twenty-three Denison University undergraduates viewed bilateral-stream RSVP displays containing black-letter distractors and two targets –a salient red letter, and a less salient black digit. These two targets were presented in opposite hemifields simultaneously or at various asynchronies. Temporal order judgments (TOJs) and simultaneity judgments of the targets occurred in separate daily sessions, counter-balanced across participants. Retinal stimulation remained identical across the two tasks. Results: Psychometric functions for the TOJ task revealed that participants perceived LVF targets ~130 msec earlier than RVF targets (p=0.00001). Participants' simultaneity judgments exhibited criterion shifts that depended significantly on the salient target's (red letter's) hemifield; mean target asynchronies associated with subjective simultaneity ranged between ~93 and ~123 msec briefer for LVF- than RVF-salient-targets (p=0.025). Intriguingly, participants misperceived brief (133 msec) asynchronies as "same" significantly more often (p=0.0001) when LVF-salient-targets preceded, rather than followed, less salient RVF targets. This error pattern would be expected if participants "remapped" LVF-salient-targets to a later point in the RSVP stream, to counteract hastened neural responses to LVF stimuli. Conclusion: Our TOJ data demonstrate hastened perception of LVF targets by durations approximating one cycle of visual attention's canonical ~10 Hz temporal resolution. Our findings further suggest humans can unknowingly compensate for ("remap") a hastened neural response to LVF targets by using hemifield-specific rules within the decision-stage of simultaneity judgments.

56.456 Reduced temporal fusion in near-hand space

Stephanie Goodhew[1,2](s.c.goodhew@gmail.com), Davood Gozli[2], Susanne Ferber[2], Jay Pratt[2]; [1]Research School of Psychology, The Australian National University, [2]Department of Psychology, University of Toronto

Humans make several eye movements every second, and objects themselves move in the environment. This means that brain receives interrupted input, from which it is necessary to draw inferences about whether stimulation reflects a single object continuing through time, or instead reflects discrete object identities. Here we investigated whether such processes of object integration versus individuation could be influenced by the temporal resolution of encoding. To do this, we used object substitution masking

(OSM), which refers to a situation in which the perception of a briefly-presented target (e.g., Landolt C) surrounded by four dots is obscured when the four-dots have a delayed offset relative to the target. OSM is thought to reflect a failure to segregate the target from mask, which means that increasing the temporal precision of the visual system should reduce OSM. In the present study, temporal precision was manipulated through the proximity of observers' hands to visual stimuli, as near-hand space has been recently been found to enhance activity in the magnocellular visual pathway (which has high temporal resolution). Observers' task was to identify the location of the gap in a target broken circle (left or right of the object) surrounded by four dots, which either offset simultaneously or temporally trailed for 200ms. The observers made responses via a mouse attached to either side of the screen (visual stimuli in near-hand space) and in a separate block via keys on the keyboard (visual stimuli not in near-hand space). Hand placement did affect OSM: there was significantly less masking (i.e., increased target identification accuracy) for stimuli in near-hand space. This finding demonstrates that OSM can be conceptualized as a failure of object individuation, and this process can be facilitated by increasing the temporal resolution of vision via the proximity of visual stimuli to the hands.

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56.457 **Right hemisphere dominance in temporal attention: a TMS study** Lorella Battelli[1,2](lbattell@bidmc.harvard.edu), Florian Herpich[1], Sarah Tyler[3], Emily Grossman[3], Sara Agosta[1]; [1]Center for Neuroscience and Cognitive Systems, Italian Institute of Technology, Rovereto, Italy, [2]Berenson-Allen Center for Noninvasive Brain Stimulation and Department of Neurology, Beth Israel Deaconess Medical Center, Harvard Medical School, [3]Visual Perception and Neuroimaging Lab, Department of Cognitive Sciences University of California Irvine

Right posterior parietal cortex (rPPC) shows an advantage over the left (lPPC) for spatio-temporal computations (Tyler et al., VSS 2012). Patients with right but not left parietal lesion show impaired temporal attention across the entire visual field (Battelli et al., 2008). Here, the role of the rPPC in events discrimination across time was investigated using an offline TMS paradigm. 10 participants were administered a judgment-of-simultaneity task and asked to discriminate whether two flickering dots among four (two in the left and two in the right visual field presented simultaneously) were flickering in- or out-of-phase. We used a staircase procedure to measure their phase discrimination threshold in both visual fields. We compared performance at baseline, immediately after and 30min after 20min 1Hz stimulation. We stimulated the left, right PPC and early visual areas (EVA) in three separate counterbalanced sessions. At baseline, thresholds were significantly higher in the left compared to the right visual field (average of 10 and 9 Hz for the left and right field respectively), supporting the hypothesis of a right hemispheric specialization in temporal computation. Moreover, TMS caused a significant reduction of the phase discrimination threshold in the left visual field after stimulation over the rPPC, while it had no effect over the lPPC or EVA. While these data mimic patients' neglect-like performance in the field contralateral to right parietal lesion, they do not replicate the bilateral deficit found in chronic patients. Our TMS data show that our temporary disruption likely reduced the inhibition that the dominant rPPC exerts over the lPPC, allowing the lPPC to compensate for stimuli presented in the right field. The differences between TMS and patients' data might be due to intra- and inter-hemispheric dynamic between cortical areas that are differently affected by a stroke compared to the temporary inactivation caused by TMS.

Eye Movements: Neural mechanisms, perception

Tuesday, May 14, 2:45 - 6:45 pm

Poster Session, Vista Ballroom

56.501 **Visual Sensitivity of Frontal Eye Field Neurons During the Preparation of Saccadic Eye Movements** Rebecca Krock[1](bkrock@stanford.edu), Tirin Moore[1,2]; [1]Department of Neurobiology, Stanford University School of Medicine, [2]Howard Hughes Medical Institute, Stanford University School of Medicine

Saccadic suppression is a well-characterized psychophysical phenomenon in which visual sensitivity decreases profoundly just before and during saccades. It could play a role in minimizing the perception of self-generated motion signals. The visual responses of neurons before and during saccades have been investigated at numerous stages of the primate visual system, but the relationship between saccadic modulations of visual responses and suppression of psychophysical contrast sensitivity remains unclear. Furthermore, no evidence of a correlate has been observed in the frontal eye field (FEF), which in addition to representing visual information also plays a role in generating saccadic eye movements. To obtain a more direct comparison with psychophysical measurements of saccadic suppression and determine whether a correlate is present in the FEF, we measured not just visual responses but also the contrast sensitivity of neurons in the FEF during the preparation of saccades. We functionally characterized neurons as having visual, visuomovement, or movement activity using a memory-guided saccade task. For cells with visual or visuomovement activity, we recorded responses to brief visual probes (8 ms, full-field, 0.1 cycles/degree sinusoidal gratings ranging from 2% to 32% Michelson contrast). To quantify suppression, we compared the contrast sensitivities measured from contrast-response functions for probes presented long (>100ms) and immediately (<100ms) before saccades. Our results suggest a means by which the representation of visual stimuli in the FEF might account in part for the changes in visual sensitivity that precede saccades.

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56.502 **Temporal structure in the lateral intraparietal area (LIP) neuronal activity during dynamic visual search** Koorosh Mirpour[1](kmirpour@mednet.ucla.edu), James Bisley[1,2,3]; [1]Dept. Neurobiology, [2]Jules Stein Eye Institute, David Geffen School of Medicine, [3]Dept. of Psychology and the Brain Res. Inst., UCLA, Los Angeles, CA

The ability to recognize targets from distractors is as crucial as remembering where you have looked when performing dynamic visual search. We have shown that activity in LIP encodes all these elements; the average spiking responses of LIP neurons not only differentiate between targets and distractors, but also keep track of already visited locations during visual search. It has also been shown that the power spectra of LIP activity exhibits a spatially tuned temporal structure in memory guided eye movements. However it has not been shown whether there is temporal structure in LIP activity during dynamic visual search. To address this question, we recorded local field potentials (LFPs) from LIP while two animals performed a visual foraging task. In this task, animals search through an array of 5 task irrelevant distractors and 5 Ts, one of which has a reward linked to it (the target). To obtain the reward, the animal must fixate the target for 500 ms. The stimuli are arranged such that when the animal fixates one stimulus, another is likely to be in the response field of the single neuron being recorded when the LFP was collected. We found that raw LFPs distinguished between the Ts and the irrelevant distractors in addition to new from visited objects. In the spectral analysis of the LFP, we found the temporal structure related to efficient foraging behavior. The spectral power in the mid-gamma band differentiated targets, distractors and visited objects. In addition there was an elevation of power in alpha band which appeared much earlier and was only present when an already visited object was in the receptive filed. We suggest that this signal, which may be a neural correlate of search memory, or inhibition or return, is separate from the feed-forward signal that differentiates between the stimulus classes.

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56.503 **Neuronal population activity in area 8a of macaques predicts saccade end point** Sebastien Tremblay[1](sebastien.du.tremblay@mail.mcgill.ca), Lia Asquini[1], Adam Sachs[2], Florian Pieper[3], Julio Martinez[1]; [1]Department of Physiology, McGill University, Canada, [2]Department of Neurosurgery, Stanford University, [3]Institute for Neuro & Pathophysiology, University Medical Center Hamburg-Eppendorf (UKE), Germany

Previous electrophysiological studies have demonstrated that single neurons in area 8a of macaques are involved in the planning and execution of saccadic eye movements. However, most of these studies have recorded from one neuron at a time and pooled neuronal responses over multiple non-simultaneous single trial presentations of the same condition. This procedure assumes that responses of single neurons are independent (non-correlated), an assumption that has proven to be erroneous. Here, we implanted 96-channels multielectrode arrays in the area 8a of two macaques and recorded single and multiunit activity while they performed a visually guided saccade task to one out of four simultaneously presented targets. Simultaneous neuronal spiking activity aligned to the initiation of the saccade was inputted into a support vector machine (SVM) algorithm to optimize a model predicting to which quadrant of the screen the monkey would saccade. Including all neurons, the model achieved 67% accuracy in predicting saccade end point. Including only neurons with significant spatial tuning increased the model accuracy to 94%. Interestingly, the analysis period that yielded the best accuracy spanned from saccade initiation to 80 msec before, longer or shorter time intervals slightly diminishing model performance. In order to assess the effect of the simultaneity of the neuronal activity on model performance, we destroyed simultaneity by shuffling trials' identity within experimental conditions, which concomitantly abolishes noise correlations. Surprisingly, noise-correlations-free activity yielded significantly better prediction accuracy both when all neurons were included (+9%) and when only spatially tuned neurons were selected (+4%). These preliminary results suggest that neuronal population activity in the macaque area 8a can be decoded to predict stereotyped saccade end point with high accuracy, and that noise correlations have a slight detrimental effect on population decoding using a SVM classifier.

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56.504 **Distributed cortical representation of eye gaze directions during free viewing of a feature-length movie** Florian Baumgartner[1](florian.baumgartner@ovgu.de), Michael Hanke[1], Stefan Pollmann [1,2]; [1]Department of Experimental Psychology, Otto-von-Guericke-Universität Magdeburg, [2]Center for Behavioral Brain Sciences, Magdeburg

Over the last decades the majority of studies that investigated the neuronal basis of visual attention and the tightly coupled oculomotor system employed paradigms in which the attention shifts and associated eye movements were highly controlled by a given task and a distinct set of artificial stimuli. Few studies examined how attention and eye-movement control interact during a complex and rich visual input which simultaneously drives bottom-up as well as the top-down attention. This study investigates where in the human cortex gaze and attention shifts made during dynamic visual stimulation are represented. We recorded fMRI data as well as gaze position in two independent subjects groups (10 subjects each) while they freely watched the action movie "Indiana Jones: Raiders of the Lost Ark". Subjects showed highly similar eye movements over the full length of the movie. This allowed for establishing a common model of spatial distribution of gaze position and visuospatial attention. Using a searchlight approach we identified brain areas showing correlated similarity structures of gaze heatmaps and fMRI data by using representational similarity analysis as a multivariate pattern measure. We could confirm the association with parts of dorsoparietal (MNI x 50, y -24, z 32) attentional network and the dorsolateral prefrontal cortex (MNI x 54, y 38, z 10) being linked to the deployment of visual attention in a complex audiovisual environment. The corresponding areas show a strong right hemispheric bias. Additionally, activity patterns in the medial frontal cortex (MNI x 8, y 54, z4) may reflect the deployment of visuospatial attention. Our results demonstrate that a widely distributed network including ventral and dorsal parts of the attention system contributes to the deployment of location specific attention during movie watching.

56.505 **Peri-microsaccadic modulation of visual activity in the primate superior colliculus: dependence on movement direction and neuronal cell type** Chih-Yang Chen[1,2](chen.chih-yang@cin.uni-tuebingen.de), Ziad M. Hafed[2]; [1]Graduate School of Neural and Behavioural Sciences, International Max Planck Research School, [2]Werner Reichardt Centre for Integrative Neuroscience

Perceptual thresholds are elevated around the time of microsaccades. A neural correlate for such 'microsaccadic suppression' has recently been described in superior colliculus (SC) (Hafed & Krauzlis, 2010), but the dependence of this 'suppression' on visual location, microsaccade direction, or neuronal cell type is currently unknown. Here we tested for such dependence, to fully understand how microsaccades affect perceptual performance. We recorded SC activity from one monkey fixating a white spot over a gray background. Inside a neuron's response field (RF), we displayed a square (1-5 deg) containing a vertical sine-wave grating (2.2 cpd) for ~250 ms. We measured peak neuronal activity 50-150 ms after grating onset and divided trials into three groups: 1) the grating appeared without microsaccade <300 ms from its onset; 2) the same grating appeared <100 ms before microsaccades; 3) the grating appeared <100 ms after microsaccades. We recorded 'visual-motor' and 'visual-only' SC neurons. Across 49 neurons (29 visual-motor and 20 visual-only), most (~94%) exhibited peri-microsaccadic modulation of visual activity. The most common observation was strong suppression for stimuli appearing right after microsaccades (~90% of visual-motor neurons and ~65% of visual-only neurons). For stimuli appearing before microsaccades, the neuronal modulations depended both on cell type and movement direction. Specifically, for microsaccades away from the RF location, most visual-motor neurons (~62%) were suppressed; for microsaccades toward the RF, ~38% showed suppression and ~24% enhancement. For visual-only neurons, only ~5% showed suppression for stimuli before microsaccades and ~70% showed enhancement, irrespective of microsaccade direction. Thus, peri-microsaccadic modulation of SC visual activity is pervasive, with specific differences between neuronal cell types. Besides providing a more complete characterization of peri-microsaccadic changes in vision, our work reveals a possible neural basis for recent observations that microsaccade direction has a strong, eccentricity-dependent influence on perceptual performance (Hafed, Society for Neuroscience Meeting, 2012).

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56.506 **Shared neural sensory signals for eye-hand coordination in humans** Li Li[1](lili@hku.hk), Diederick C. Niehorster[1], Dorion Liston[2,3], Wilfred W.F. Siu[1], Lee Stone[2]; [1]Department of Psychology, The University of Hong Kong, Pokfulam, Hong Kong SAR, [2]Human-Systems Integration Division, NASA Ames Research Center, [3]San Jose State University

Eye-hand coordination is a central research topic in neuroscience and cognitive psychology. There has long been a debate on whether eye-hand coordination is limited by shared neural sensory signals that drive both the eye and hand sensorimotor systems, or by independent signals later in sensorimotor pathways. In this study, we addressed this question by examining the correlation between the tracking errors in the ocular and manual responses. Two experimental conditions were tested: in the eye-hand condition, as participants used pursuit eye movements to track the movement of a Gaussian target (σ=0.6°) on a computer display (40°H x 30°V) as its horizontal position was perturbed by the sum of seven harmonically-unrelated sinusoids (0.1-2.19 Hz), they also used a high-precision mouse to control the horizontal position of a second vertically-offset Gaussian cursor (8° below) to align it with the pursuit target. In the eye-alone condition, the target and cursor positions previously recorded in the eye-hand condition were played back, and participants were instructed to use only pursuit eye movements to track the movement of the target. Prior to computing the correlation between the tracking errors in the ocular and manual responses, for each 90-s trial, we subtracted best-fitting linear tracking responses at the seven input perturbation frequencies to remove direct correlation with the visual stimulus. Across 13 participants, trial-by-trial examination revealed that the correlation between the residual noises (i.e., tracking errors) in the ocular and manual responses in the eye-hand condition (mean r=0.20; range: 0.08-0.34) was highly significant (p<0.0001, Pearson's R), and in all but seven out of 78 cases (13 subjects x 6 trials) higher than the spurious correlation in the eye-alone condition when ocular pursuit was not accompanied by simultaneous manual tracking. We conclude that common neural visual motion signals drive both the eye and hand sensorimotor systems.

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56.507 **How does implicit learning of search regularities alter the manner in which you search?** Gerald McDonnell[1](gmcdonnell@huskers.unl.edu), Mark Mills[1], Leslie McCuller[1], Mike Dodd[1]; [1]University of Nebraska-Lincoln

Individuals are highly sensitive to statistical regularities in their visual environment, even when these patterns do not reach conscious awareness. For example, substantial savings in search time is observed when some or all aspects of distractor/target configurations repeat (e.g., Chun & Jiang, 1998; Song & Jiang, 2005). Moreover, when encoding and subsequently recognizing photographs, scanpaths tend to repeat over multiple viewings (e.g., Foulsham & Underwood, 2008). Here, we examine whether oculomotor behavior is systematically altered when images and distractor/target configurations rarely repeat, but target location on an initial trial always predicts the general location of a target on the subsequent trial (e.g., a target in the lower left quadrant on trial N means the target will appear somewhere in the upper right quadrant on trial N+1). Participants search for a target through a gaze contingent window in a display consisting of multiple distractors and provide a discrimination response (target present/absent). Critically, no visual information is presented at fixation to bias initial eye movements. The results of Experiment 1 are consistent with the adaptive scanning hypothesis (Myers & Gray, 2010) in that participants demonstrate a search time reduction based on the learning of the statistical regularity and this seems primarily due to a) the same general scanpath repeating and b) increased efficiency of search due to fewer fixations and lesser dwell in each quadrant across trials. Importantly, however, this effect is not attributable to serial scanning order as detection of a target on N does not alter the likelihood that the correct quadrant will be fixated first on N+1. In follow-up experiments, participants are forced to vary their search order strategy to determine whether a bias based on the learned regularity would emerge. Collectively these experiments influence our understanding of the manner in which learned regularities affect oculomotor behavior.

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56.508 Characteristics of ambient and focal processing during the visual exploration of aerial and terrestrial scenes Sebastian Pannasch[1](pannasch@psychologie.tu-dresden.de), Jens R. Helmert[1], Bruce C. Hansen[2], Adam M. Larson[3], Lester C. Loschky[3]; [1]Applied Cognitive Research Unit, Department of Psychology, Technische Universitaet Dresden, Germany, [2]Department of Psychology & Neuroscience Program, Colgate University, [3]Department of Psychology, Kansas State University

Eye movements during free exploration of real-world scene imagery often show a pattern of longer fixation durations over time, but decreasing saccade amplitudes which has been explained as a shift from ambient (global) to focal (local) processing. In the present study, we asked whether these established spatio-temporal eye movement patterns would extend to scenes deviating from our everyday experience, namely aerial scene views. Previous research showed that gist processing takes longer for aerial than terrestrial views, and aerial views were unaffected by scene rotation, unlike terrestrial views (Loschky, Ellis, Sears, Ringer, & Davis, 2010). The latter finding suggested that terrestrial views are processed holistically, with aerial views being processed featurally. Because the focal mode is associated with processing object features, we asked whether aerial views engender more focal processing than terrestrial views. Alternatively, since aerial view gist processing takes longer, perhaps the ambient mode would last longer when viewing aerial than terrestrial scenes. To test these competing hypotheses, we showed 30 viewers both aerial and terrestrial scenes, either upright or inverted, for 6.5 seconds, and analyzed their eye movements. For aerial views, we found prolonged first fixation durations, consistent with aerial gist processing taking longer. Thereafter, we found that the ambient-to-focal strategy was preserved across both perspectives, but for aerial views both, fixation durations and saccade amplitudes were longer. Furthermore, for aerial views, scan paths were less similar between observers, and fixation locations were better predicted by visual saliency, consistent with the idea that processing of aerial scenes requires more "bottom-up" processing than terrestrial scenes. Thus, the results confirm the stability of the ambient-to-focal shift for scenes deviating from our normal experience. However, the greater processing effort might be reflected by a hybrid processing mode that was part ambient (long saccades) and part focal (long fixations).

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56.509 Visual search during motion perception Mariagrazia Benassi[1](mariagrazia.benassi@unibo.it), Giulia Baroni[2], Luisa Lugli[2], Roberto Bolzani[1], Roberto Nicoletti[2]; [1]Department of Psychology, University of Bologna, [2]Department of Communication Studies, University of Bologna

Eye movements during motion tracking or smooth pursuit have been widely investigated. However, it is still unclear how eye movements and motion perception system are related. We aim to analyze the pattern of gaze during coherent motion perception in absence of tracking at the very early stage of the motion perception process. Moreover, we would measure if good performances in motion perception are guided by specific gaze pattern. We measured the gaze in twenty-five healthy subjects using eye tracker system (SMI500) during motion perception tasks (coherent motion test), and during visual search of static elements (i.e. searching coloured dots within a group of white dots). The subjects are divided in two groups: good motion perception performers (scoring above the 50% of the total trials) and bad motion performers. The gaze is analyzed by means of specific parameters obtained from the eye movements recordings: the length of the eye movement track plotted on a bidimensional plane, the area of the confidence ellipse of the eye position, the standardized length (obtained by the ratio between the length and the area of the confidence ellipse), the flattening and the slope of the confidence ellipse. Significant differences in gaze patterns are found between motion perception and static visual search tasks. The gaze during motion perception is characterized by stronger flattening of confidence ellipse and longer length of eye movement track. The good performers have significantly longer length and standardized length of the eye movements track as compared to bad performers. These results show that the motion detection requires longer gaze path with respect to static visual search and that the path length is longer in good than in bad performers. In conclusion, the efficiency in motion detection is related to longer length of the gaze path (i.e. mean velocity) more than to the area scanned by the different gaze positions.

56.510 Effects of spatial frequency on fixation durations within scenes Jennifer Olejarczyk[1,2](olejarcz@email.sc.edu), Steven G. Luke[1,2], Joseph Schmidt[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

An important question in scene perception research is the degree to which individual fixation durations reflect perceptual and cognitive processing. The present study examined this issue by measuring the effect of moment to moment changes in the spatial frequency content of presented scenes on fixation duration. Eye movements were monitored while subjects performed a free-viewing memorization task. During saccades prior to critical fixations, scenes changed to low-pass filtered or unfiltered versions of the original image. The image reverted back to its original unfiltered form during the saccade following the critical fixations. Results from a linear mixed effects model showed significantly longer fixations as the changed image became more degraded. The unfiltered image produced significantly shorter fixation durations than any of the filtered images. These results are the first to show an immediate and monotonic relationship between fixation duration and the spatial frequency content of the scene during that fixation, and are consistent with previous research showing a similar effect of luminance on fixation durations (Henderson, Nuthmann & Luke, in press). We outline how these results are consistent with the predictions of the CRISP model of saccade generation in scenes (Nuthmann, Smith, Engbert & Henderson, 2010), which proposes that difficulty in moment-by-moment visual and cognitive processing of the scene modulates fixation durations.

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56.511 Fractal Dynamics of Visual Search as a Function of the Gestalt Law of Proximity Attila Farkas[1](farkas.attila@eagles.usm.edu), Alen Hajnal[1]; [1]Department of Psychology, University of Southern Mississippi

The current project examined the effect of the Gestalt Law of proximity on visual cognition. Proximity can be directly quantified as the distance between adjacent objects in a visual array. Recent studies on eye movements have revealed the interactive nature of self organizing dynamic processes in visual cognition (Stephen & Mirman, 2010). Aks, Zelinsky, and Sprott (2002) found that visual search patterns are not randomly distributed, and that a simple form of temporal memory exists across the sequence of eye movements. We quantified the law of proximity using long-term autocorrelations of the time series of successive gaze locations, fixations, and response times. Eye movements were recorded during a typical visual search task (find a T shape among distracters). The stimuli were distributed either as equidistant elements, as rows with small horizontal inter-element distances, or as columns with smaller vertical inter-element distances. Long reaction times and large number of fixations were associated with increased task difficulty. More fixations were used for vertically organized stimuli in nonhomogenous trials, as compared to horizontal organization. Localizing targets was easier for horizontally organized stimuli, as indicated by quicker reaction times and fewer fixations. During the transition from homogenous to horizontally organized patterns participants made more fixations, and invested more time localizing targets than during the transition toward vertical organization (columns). This was also reflected in a more dynamic, nonrandom search process that alternated between short and long reaction times during the transition toward horizontal row structure, as revealed by antipersistent fractal structure of reaction time fluctuations with an average Hurst exponent less than 0.5. We concluded that the preference toward, and facilitation of horizontal organization patterns is consistent with previous findings that showed greater ease and frequency of vertical compared to horizontal eye movements in visual search tasks (Aks et al, 2002; Oyama, 1961).

56.512 The perception of depth induced by texture gradient can partly control vergence. Kristin Osk Ingvarsdottir[1](Kristin.Osk_Ingvarsdottir@lucs.lu.se); [1]Lund University Cognitive Science, Sweden

Traditionally, vergence eye movements are considered to be elicited by binocular depth cues. Nevertheless, studies have revealed similar eye movements at some degree when perceiving monocular depth cues during monocular viewing (Ringach, et al. 1996. Vision Res, 36: 1479-1492) and binocular viewing (Ringach, et al. 2011. J. Neurosci, 31: 17069-17073). The aim of current study was to see whether previous results could be generalized to texture gradient viewed in a binocular condition. A Hi-Speed tower-mounted eye tracker was used to binocularly measure eye movements of 7 subjects participating in a visual-search task. The task was to search for a dot presented in various locations on a background that either had texture gradient or no depth cue at all. It was assumed that the vergence would be in line with the depth provided by the texture gradient. Thus the eyes would converge when looking at a dot appearing closer to the viewer, and diverge when appearing further away, despite the fact that the physical distance was always the same. In contrast to previous results I found that the perception of texture gradient could only partly generate vergence response and that effect was weak and disappeared quickly. I conclude that, in binocular viewing, the perception of texture gradient does not manage to override

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the binocular cues completely. Nevertheless, the thought of seeing depth is enough to generate mild vergence response. My findings are discussed in terms of conflicting theories on vergence control and depth perception, where it is debated whether vergence are only elicited by the properties of the visual input, or if they are also emitted by the perception of the input.

56.513 **Allocation of attention during cognitive conflict: Evidence from eye movement patterns during a Stroop task** Bettina Olk[1](b.olk@jacobs-university.de); [1]School of Humanities and Social Sciences, Jacobs University, Bremen, Germany

Attention plays a crucial role in the Stroop task, which requires attending to less automatically processed task-relevant attributes of stimuli and the suppression of involuntary processing of task-irrelevant attributes. The experiment assessed the allocation of attention by monitoring saccades and fixations throughout congruent and incongruent trials in a numerical version of the Stroop task. Participants viewed two stimulus arrays that differed regarding the amount of items and their numerical value. They judged by manual response which of the arrays contained more items. In the congruent condition the larger array of items consisted of numbers with higher value, e.g., 44444, than the numbers of the smaller array, e.g., 222. In the incongruent condition the larger array of items was composed of numbers with lower value, e.g., 22222, than the numbers of the smaller array, e.g., 444. Manual reaction times were slower in the incongruent than in the congruent condition, indicating that the task-irrelevant attribute - the value of the numbers - is processed involuntarily and slows down responding. Further, different viewing patterns were observed between congruent and incongruent trials. The direction of first saccades was guided by task-relevant information (more items) but in the incongruent condition directed more frequently towards task-irrelevant information (higher value). The data further suggest that the difference in the deployment of attention between conditions changes throughout a trial, likely reflecting the impact and resolution of the conflict. For instance, stimulus arrays in line with the correct response (more items) were attended for longer and fixations were longer for incongruent trials, with the second fixation and considering all fixations. By the time of the correct response, this latter difference between conditions was absent. Possible mechanisms underlying the allocation of attention as reflected by eye movement patterns in a conflict task are discussed.

56.514 **The difference between temporal order judgment during voluntary and automatic saccades** Yoshiko Yabe[1](yy47151@gmail.com), Hiroaki Shigemasu[2]; [1]Research Institute, Kochi University of Technology, [2]School of Information, Kochi University of Technology

Purpose Previous studies have reported that our perception of time is modulated during or just before or after eye movements. When two events occur within a very short interval before saccadic eye movements, the order of them is perceived inversely (Morrone et al., Nat Neurosci, 2005). This phenomenon indicates that we perceive events which occur according to time neither in real time nor predictively at the moment. Here, we examined what types of saccades induce the phenomenon, which enables to investigate the key factor of retrospective perception, i.e. 'postdiction'. Methods: We presented two brief bars that marked intervals between 40 and 130 ms just after the saccadic trigger and asked participants to judge their order. There were two conditions of the trigger (CNG and OFF conditions). Under the CNG condition, both fixation square and saccadic target were presented throughout the trial. Participants made a saccade when the fixation square became a circle. Under the OFF condition, the fixation point disappeared and the saccadic target appeared at the same time. The automaticity of the saccades should be higher under the OFF condition than under the CNG condition because visual grasp reflex would have occurred when the saccadic target appeared. We also manipulated the duration between the presentations of the bars and the saccadic trigger between two conditions because the saccadic delay was longer under the CNG condition than under the OFF condition. Results: The trials in which the mean of the time points of two bars was 100 ms or less before saccadic onset were analyzed. Proportion correct was above chance only under the CNG condition. Conclusion: When the saccadic trigger caused visual grasp reflex, error rate of the temporal order judgment increased. Our results suggest that automaticity of saccades involve the modulation of time perception.

Eye movements: Saccades

Tuesday, May 14, 2:45 - 6:45 pm

Poster Session, Vista Ballroom

56.515 **Contextual adaptation in saccades to moving targets** 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 can be contextual: maintaining two different gain (saccade/target amplitude) parameters for the same vector. For example, different orbital positions can serve as contexts for separate gain states. We have previously shown that even visual properties of the target can also be used as a context, implying a general form of associative learning. We hypothesize that a more specific natural use of contextual saccade adaptation might be in adapting saccades to moving targets. In this study, we explore using different direction of movement as a context for saccade adaptation for the first time. Methods: While maintaining central fixation, 10 subjects viewed a circularly moving target (1/16 Hz, clockwise or counterclockwise) at 8-10 degrees eccentricity in the upper right quadrant. When the target was in a sector between 15 and 75 degrees, the fixation point disappeared and subjects initiated a saccade to the moving target, which remained visible for 400ms post-saccade. After a baseline phase, clockwise targets were stepped outward by 2 degrees upon saccades, and counterclockwise targets stepped inward by 2 degrees. Results: During the baseline phase, we found no gain differences in saccades to the oppositely moving targets. In 9/10 subjects, the adaptation phase induced gradual and significant contextual adaptation of saccades: same vector saccades either increased or decreased their gains to clockwise or counterclockwise targets, respectively. These differences persisted in a post-adaptation phase. Conclusion: We conclude that motion direction can act as a strong contextual cue for saccade adaptation. This contextual adaptation can assist in extrapolating visual motion information in coordinating saccadic and smooth eye movements.

56.516 **Ultra-rapid Saccade Adaptation: Effective in Under Three Minutes** Michael Gray[1](michaelgr87@gmail.com), Annabelle Blangero[1], James Herman[1], Mark Harwood[1]; [1]Biology Department, City College of New York

Introduction. Consistent mismatches between saccade landing positions and their intended targets are compensated for by a saccade adaptation process that increases or decreases saccade amplitude to minimize errors. It has been shown that feedback from these errors is most influential within the first 100ms after a saccade. Nonetheless, conventional paradigms involve much longer post-saccadic viewing durations with trials lasting several seconds. Here we propose an efficient and equally effective saccade adaptation paradigm in which subjects make saccades almost continuously, greatly reducing experiment duration while suffering no reduction in adaptation magnitude. Methods. During these 'ultra-rapid' adaptation sessions, subjects (n=7) made horizontal saccades to a red annulus (0.3°), which randomly stepped 10° to the left or right of its previous location ~60ms after a saccade landed. After an initial baseline period, the rapidly stepping target made additional intrasaccadic steps of 2°, inducing inward or outward adaptation depending on the session. Ultra-rapid adaptation sessions were compared to 'regular' adaptation sessions with post-saccadic trial durations of ~1.5sec. Sessions lasted either 250 trials (ultra-rapid: 2.5min; regular: 7min) or 800 trials (7min; 25min), allowing us to compare effects of both trial number and experiment duration on adaptation magnitude. Results. Remarkably, for 250-trial inward adaptation, adaptation magnitude was significantly greater for the ultra-rapid session ($t=3.68$, $p=0.01$). Otherwise, there were no significant differences in adaptation magnitude between ultra-rapid and regular paradigms for both inward and outward forms of saccade adaptation when there were equal trial numbers. Conclusions. This novel paradigm provides an extremely time-efficient method for inducing saccade adaptation, which is of potentially great benefit for experiments requiring many trials or examining clinical populations. Our findings also have theoretical implications for the time-dependent mechanisms underlying saccade adaptation and motor learning in general.

Acknowledgement: NSF-BCS0842464

56.517 **Retention of oculomotor changes after adaptive lengthening of voluntary saccades** Ouazna Habchi[1](ouazna.habchi@inserm.fr), Roméo Salemme[1], Christian Urquizar[1], Denis Pelisson[1]; [1]ImpAct Team (Integrative, Multisensory, Perception, Action and Cognition), Lyon Neuroscience Research Center (CRNL), INSERM U1028-CNRS5292

Adaptation of saccadic eye movements is one of the most studied model of sensori-motor adaptation. Several studies have investigated saccadic adaptation over the short-term, but the retention of adaptive oculomotor changes

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over days or weeks remains debated. Here, we tested whether the amplitude lengthening adaptation of voluntary saccades (VS) can be retained over several days. We induced adaptation in seven human subjects, using a modified version (Panouillères et al. JEMR. 2012) of the target double-step paradigm (Mc Laughlin. Percept & Psychophys. 1967). Adaptation was induced progressively by displacing the target during horizontal VS and in the same direction (forward step of 30% in the first three blocks of trials and of 45% in the last three blocks); both leftward and rightward saccades were simultaneously adapted. Saccadic gain changes relative to the pre-adaptation baseline were calculated immediately after and at five different time points after adaptation: 5 min (day 0) and 1, 5, 11, and 19 days. Results revealed significant increases of saccadic gain relative to baseline, reaching 15% and 16% immediately after adaptation of leftward and rightward VS, respectively. Further, the gain of leftward VS remained significantly elevated on days 0, 1, 5 and 11 (average saccadic gain change: 13%, 6.8%, 3.3% and 3.7%, respectively). In contrast, for rightward VS, the average change of gain remained significant on day 0 only (13 %) and decreased to a non significant 1.3% value on day 1. These data reveal that adaptation after-effects persisted up to 11 days for leftward VS but had already disappeared after 1 day for rightward VS. In agreement with a similar study of amplitude shortening adaptation of reactive saccades (RS) (Alahyane et al. Learn & Mem. 2005), these results suggest that saccade direction (leftward or rightward) interacts with the long term retention of adaptive oculomotor changes.

56.518 Adaptation of saccadic eye movements involves different coordinate systems

Delphine Lévy-Bencheton[1](delphine.levy-bencheton@inserm.fr), Denis Pélisson[1], Muriel Panouillères[1], Christian Urquizar[1], Caroline Tilikete[1,2], Laure Pisella[1]; [1]CRNL Inserm U1028 UMR5292, [2]Hôpital Neurologique Pierre Wertheimer - Neuro-ophthalmology department

Saccadic adaptation allows changes of saccade over time after repeated post-saccadic error (McLaughlin, 1967). Adaptation is known to occur in oculocentric coordinates and to be unidirectional: adaptation of rightward saccades does not transfer to leftward saccades. However, Zimmermann et al. (2011) proposed that adaptation can unfold in spatiotopic coordinates: outward adaptation of rightward scanning saccades transferred to all memory-guided double-saccades (including those performed in the non-adapted direction) such that their endpoint shifted rightward (as if the visual target was re-localized). But the authors questioned whether their subjects could have used the visible frame of the computer screen as a reference, thus allowing adaptation in allocentric -rather than in spatiotopic- coordinates. In the present study, we re-assessed this question by using targets LEDs presented in complete darkness to avoid any visual reference. Nine subjects performed the paradigm of Zimmermann et al. (2011) in this no-frame condition and in a frame condition, in two separate sessions. Repeated measures ANOVA (factors: frame/no-frame and pre/post) performed on the amplitude of leftward memory-guided double-saccades revealed a significant decrease after adaptation only when a frame was provided (interaction $p<0.01$), in agreement with the allocentric hypothesis of adaptation. Note however that the remapping processes which encode the parameters of the second saccade in this double-saccade task may have favored allocentric adaptation. Indeed, by testing memory-guided single-saccades after adaptation of rightward scanning saccades, we found a main effect of phase ($p=0.026$) but no interaction with the frame versus no frame conditions. This indicated that leftward memory-guided single-saccades significantly decreased after adaptation, with or without the frame, in agreement with spatiotopic adaptation. A last experiment testing the effect of the same adaptation on immediate single-saccades revealed oculocentric adaptation. Taken together, these three experiments indicate that the same saccadic adaptation can involve allocentric, spatiotopic and oculocentric coordinates.

56.519 Effect of sensorimotor adaptation of saccades on covert attention.

Denis Pelisson[1](pelisson@lyon.inserm.fr), Ouazna Habchi[1], Christian Urquizar[1], Alessandro Farnè[1]; [1]ImpAct team (Integrative Multisensory Perception Action Cognition Team), Lyon Neuroscience Research Center (CRNL), INSERM - CNRS - Univ. of Lyon

To interact with our environment, we continuously select visual information relevant to our goals. Visual selection is achieved via tightly inter-related overt eye-movements (saccades) and covert shifts of visuo-spatial attention. In face of perturbations, the saccadic system can adapt to maintain saccade accuracy. The possible consequences of the changes induced by saccadic adaptation on covert attention remain, however, unknown. To address this question, healthy participants (N=40) were separately submitted to one of four exposure phases: adaptation of leftward or rightward saccades ("adapt-left"/"adapt-right") or mere execution of leftward or rightward saccades ("control-left"/"control-right"). Reactive saccades were adaptively shortened, using the double-step target paradigm (McLaughlin 1967), where the target first stepped to 11° and then stepped backward to 7° during saccade. Covert attention was tested before and immediately after each exposure phase, by asking subjects to detect a visual target flashed at a random location to the right or left (±3°, ±7°, ±11°, ±15°) of a central fixation point, and to answer by button press while maintaining fixation. Results indicated that in both "adapt" groups, and as classically reported, the gain of saccades performed in the adapted direction decreased significantly (-15% on average), without any change of saccades in the non-adapted direction. In the adapt-left group, reaction times to left-sided targets decreased significantly (mean change= -7.5%), regardless of target eccentricity. No change in detection performance was observed in either control group. Surprisingly, no change in reaction time was found in the adapt-right group. In conclusion, covert spatial attention appears to be deployed more efficiently in the adapted hemi-field, but only when saccadic adaptation was induced in the left hemi-field. On-going experiments will test whether this asymmetrical coupling between adaptation and attention is a general feature applying to other types of adaptation (lengthening versus shortening of amplitude) and types of saccades (voluntary versus reactive).

56.520 Does orientation influence saccade metrics irrespective of its relevance for the task?

Delphine Massendari[1](delphine.massendari@gmail.com), Christophe Tandonnet[1], Bruno Nazarian[2], Francoise Vitu[1]; [1]Laboratoire de Psychologie cognitive (LPC, UMR 7290), CNRS - Aix Marseille Université, France, [2]Institut des Neurosciences de la Timone (INT, UMR 7289), CNRS - Aix Marseille Université, France

It is well known that the metrical properties of saccadic eye movements are strongly influenced by the extraction of low-level visual features (e.g. luminance). Higher-level, visual-cortical features (e.g. orientation) may also contribute, but it remains undetermined whether they intervene automatically, irrespective of their relevance for the task. Here, we investigated this issue in a saccade-target paradigm. We manipulated the uncertainty of target location in order to either force the extraction of orientation (maximal uncertainty) or make it unnecessary (minimal uncertainty). On each trial, the target was displayed with or without an additional, distractor stimulus on a textured background (composed of oriented-Gabor patches). The target was a vertically-elongated area, which differed from the background by its luminance, while the distractor differed from the background by its luminance, its orientation or both. In one set of blocks, the target, displayed at an eccentricity of 6.5 or 8.6°, was always 3.7° more eccentric than the distractor (blocked; minimal uncertainty). In another set, the target was 3.7° more or less eccentric than the distractor (mixed; maximal uncertainty), appearing at eccentricities of 6.5 and 8.6° or 2.8 and 4.9° respectively. Seven volunteers participated in the experiment. Results showed that irrespective of the uncertainty of target location, all types of distractors deviated the eyes away from the target, thus suggesting that both luminance and orientation were extracted even when they were not relevant for the task (i.e. the minimal-uncertainty condition). Still, the deviation induced by either luminance- or orientation-based distractors was much greater under maximal uncertainty, and often favored the execution of erroneous saccades towards the distractor. Thus, both retinal and visual-cortical features contribute to determine saccade metrics in a rather automatic, bottom-up manner, but their effect is reinforced and qualitatively different as a result of top-down processes.

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56.521 Population averaging in the distorted map of the superior colliculus: A new and simple account of systematic saccadic undershoot.

Françoise Vitu[1](Francoise.Vitu-Thibault@univ-provence.fr), Soazig Casteau[1]; [1]Laboratoire de Psychologie Cognitive, CNRS, Aix-Marseille Université

It is well known that saccadic eye movements tend to systematically undershoot the center of a single target stimulus displayed in the periphery, with the undershoot being proportional to target eccentricity (~10%). This phenomenon investigated for many years, was attributed to visual-acuity constraints, insufficient saccadic programming time as well as adaptive visuo-motor strategies. Here, we show, based on human behavioral data, that systematic saccadic undershoot more simply results from the distortion of visual space (or foveal magnification) in the motor map of the Superior Colliculus (SC), where saccade metrics are computed as a result of population averaging. In our study, eight participants were asked to move their eyes as quickly and as accurately as possible to a single peripheral target, while their eye movements were recorded. The target (a 0.25° triangle), was displayed at variable eccentricities (1-15°), and in variable directions (0, 22.5, 45, 67.5, 80 and 90°). The landing position of the initial saccade was first measured in degrees of visual angle. It was then converted in millimeters of collicular space, using Ottes et al.'s (1986) logarithmic mapping function of the SC in monkeys, in order to estimate the underlying distribution of neuronal activity. Results first confirmed that saccades were overall hypometric; irrespective of target direction, the angular landing position error became gradually greater and more variable as target eccentricity increased. The second, more surprising finding was that initial landing positions, when expressed in millimeters of collicular space, were all centered on the presumed target location in the motor map. Thus, neuronal activity likely builds up almost perfectly at the center of the stimulus pattern in collicular space, but due to non-homogenous afferent/efferent mapping, this inevitably results in the execution of hypometric saccades. Whether this reflects limited adaptability of the oculomotor system will have to be determined.

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56.522 **The gap effect is predominantly determined by the awareness of the fixation disappearance**

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Saccadic or manual reaction to a peripherally presented target is facilitated by the removal of a central fixation stimulus shortly before the onset of the target, compared to when the fixation stimulus remains (gap effect). The present study examined whether the perceptual disappearance of a fixation point is sufficient to induce the gap effect. Observers performed a reaction task in which they were required to fixate a central fixation point and make a saccade to the peripherally presented target (either the right or left of the fixation point) as quickly and accurately as possible. To discriminate the effects of perceptual and physical disappearance of a fixation point, we employed a consciously invisible fixation point that was suppressed by using binocular rivalry and continuous flash suppression technique. In a trial, a fixation point was presented to both dominant and suppressed eyes. Then, the fixation point was either (1) remained in both eyes, (2) remained in the suppressed eye while removed from the dominant eye, (3) removed from the suppressed eye while remained in the dominant eye, (4) removed from both eyes. A control experiment confirmed that observers were not aware of the existence, and hence disappearance, of the fixation point to the suppressed eye. The result shows that there was a significant main effect of the removal of a fixation point from the dominant eye, which leads to the gap effect. On the other hand, no such an effect was found by the removal from the suppressed eye, although a small simple effect was found when the fixation was removed from the dominant eye. Taken together, irrespective of the physical existence or disappearance of unnoticeable fixation point, the gap effect was mainly determined by the disappearance of the consciously visible fixation point.

Acknowledgement: Grant-in-Aid for JSPS Fellows

56.523 **Target range properties do not influence oculomotor undershooting bias.**

Caitlin Gillen[1](cgillen@uwo.ca), Jeffrey Weiler[1], Matthew Heath[1]; [1]School of Kinesiology and Graduate Program in Neurosciene, University of Western Ontario

An exemplar property of goal-directed saccades is the undershooting of veridical target location: a property that has been tied to an energy minimizing bias that reduces the physiological and psychological costs of target overshooting. Interestingly, however, Kapoula (1985) reported that task properties and the range of target eccentricities presented within discrete trial blocks engenders a saccade overshooting bias (so-called range effect). In the present investigation, we sought to determine whether the range of target eccentricities associated with serially presented blocks modulates saccade endpoint bias. To that end, participants (N=20) completed saccades to briefly (i.e., 50 ms) presented targets in two separate blocks. The first block employed a "small" range of target eccentricities (i.e., 3, 5.5, 8, 10.5, and 13o), whereas the second block entailed a "large" range of eccentricities (i.e., 10.5, 13, 15.5, 18, and 20.5o). Notably, the ordering of blocks was constant and two common eccentricities were associated with each (i.e., 10.5 and 13o). Thus, if a range effect influences goal-directed saccades then the undershooting bias associated with the 10.5o and 13o targets in the first block should exhibit an overshooting bias in the second block. Results for saccade amplitude revealed a reliable undershooting of all target eccentricities in both blocks. Moreover, a between-block comparison of the congruent target eccentricities (i.e., 10.5o and 13o) yielded an equivalent undershooting bias. Therefore, results provide no evidence to support a range effect in oculomotor control. Instead, the results are consistent with models of energy minimization and the assertion that oculomotor responses are designed to minimize movement time and energy expenditure. This study was supported by the Natural Sciences and Engineering Research Council of Canada (NSERC).

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56.524 **Shared positional noise in manual reaching and saccadic eye movements**

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Coordination between multiple motor systems requires effecting a motor goal in several coordinate frames. Variability in movement amplitude could, in theory, arise at one of several levels of sensorimotor processing, from input sensory noise in a central estimate of target location to output motor noise that contributes to behavioral variability. To test for a central source of sensory variability in the estimate of target location, we measured and compared movement endpoints for manual reaching and saccadic eye movements. Methods. Supine observers (n = 11) were asked to look at and point to a dim circular spot at locations eccentric (-35 to +35 degrees horizontal, +6 to -33 degrees vertical) relative to a central fixation LED. We measured motor endpoints for the reaching movement and the saccadic (eye-in-head) movements under four vibration conditions (±0.5 Gx at 8, 12, 16 Hz plus a no-vibration control), using a high-precision head and eye tracker and two touchscreen displays located symmetrically on either side the central LED. Vibration allowed us to alter the ratio of visual to motor noise. We computed endpoint error by subtracting the movement endpoint from the target location, and tested for a shared sensory drive by correlating the residual absolute error between the two movements. Results. Across observers, overall, we found a significant ($p < 0.05$, Student's t) non-zero correlation between the magnitude of the residual error from both movement systems. Conclusions. Our results rule out the idea that completely unshared sources of sensorimotor variability dominate manual reaching and saccadic performance. Our results are consistent with the idea that a central source of sensory positional noise propagates through the encoding of target location for both motor systems.

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56.525 **Learning of peri-saccadic visual stimuli**

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Introduction: Humans naturally scan the visual scene by making fast, ballistic eye movements at about three times per sec. These saccades could potentially result in a smeared and jerky image of the world, but visual perception is clearly immune to such effects. One suggestion is that this perceptual constancy is accomplished by saccadic suppression: a sharp drop in visual sensitivity during a saccade. Saccadic suppression has repeatedly been demonstrated, but the neural mechanisms underlying it are less clear (e.g. at what level in the visual pathways does suppression occur). Specifically, it is unknown if saccadic suppression can be gated by higher level mechanisms such as selective attention. Methods: Subjects performed a visual discrimination task while their eye movements were being recorded. Using a gaze-contingent paradigm, a visual stimulus (elliptic contour) was briefly presented during the execution of a horizontal saccade. In each trial, upon saccade completion, subjects reported the orientation of the ellipse (horizontal vs. vertical). Specificity to the location of the stimulus and the direction of the saccade were assessed by testing the degree of learning transfer to novel untrained conditions. Results: Performance was measured by the slope of the psychometric function (the percent of vertical choices as a function of the ellipse axes aspect-ratio). Preliminary results suggest that subjects improve considerably in this peri-saccadic discrimination task. Improvement was generalized over different saccade directions but not over different stimuli locations. Conclusion: Perceptual learning is possible even when stimuli are presented only during a saccade. Thus, peri-saccadic visual information can be processed at will. This suggests that at least some of the behavioral suppression is caused by high-level cortical mechanisms. References: Volkmann, F. C. (1962). Vision during voluntary saccadic eye movements. Journal of Optical Society of America, 52, 571–578.

56.526 **The role of temporal information in perisaccadic mislocalization**

Maria Matziridi[1](m.matziridi@vu.nl), Eli Brenner[1], Jeroen Smeets[1]; [1]Faculty of Human Movement Sciences, Research Institute MOVE, VU University, Amsterdam, The Netherlands

Whenever things change, accurate timing of events becomes crucial. This is the case when we have to localize a brief flash that is presented near the time of a saccade. To localize the flash, retinal information about its position must be combined with extra-retinal information about the changing eye position. Any temporal mismatch between the two kinds of information will result in the stimulus being seen at the wrong place. If temporal errors are (partly) responsible for the reported mislocalization of flashes presented just before, during or just after saccades, we should be able to manipulate the pattern of mislocalization by altering the perceived time of the flash. We therefore presented a rapid sequence of five bars (one red and four black; 10 ms intervals) at different positions around the time of a saccade. The task was to localize the red bar that was always either the second or the fourth in the sequence. We hypothesised that the resolution of human temporal order judgments is too poor to accurately identify the red flash's position in the sequence, so subjects' judgements of its timing will be shifted towards the centre of the sequence. If so, the asymmetrically timed black bars will introduce a systematic temporal error: the red bar will be perceived further in the direction of the saccade when it is presented early in the sequence than when it is presented late in the sequence. The results confirmed our hypothesis, showing a different mislocalization pattern for the two positions of the red bar within the sequence. Flash positions were misjudged in accordance with the flashes having been presented closer in time to the centre of the sequence. We conclude that temporal information is crucial for judging the spatial location of stimuli that are presented briefly near the time of saccades.

Acknowledgement: Greek State Scholarships Foundation

56.527 **Role of peripheral vision in the representation of objects' spatial location**

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The role of peripheral vision in coding the spatial location of visual objects remains unclear. It has been suggested that it plays an indirect role only, providing information to guide saccadic eye movements from which efficient spatial coding is achieved (Yamamoto & Philbeck, 2012). Here we investigated whether peripheral vision might also play a more direct role through the allocentric coding of objects' location with respect to peripheral elements within real world visual scene. Subjects faced a wide-field screen and were asked to gaze and memorize the spatial location of a red dot presented on top of a real-world picture. During the learning phase, a portion of the picture surrounding the red dot was masked in order to remove central visual cues (mask diameter: 0°, 5°, 10° or 20°). After a delay with a grey screen during which subject made a saccade, the real-world picture was presented again and subjects had to point to the memorized location of the red dot on the picture using a laser. Crucially, the reappearing picture could be shifted 3° to the left or to the right, inducing a conflict between the spatial locations defined by visual information contained in the picture or by saccadic and other extra-visual information. Although the shift was unnoticed by the subjects, pointing responses were significantly impacted and biased toward the shift. The relative weight of visual information in estimated locations decreased gradually with increasing mask diameter: 100% with no mask, 60% with 5° mask, 40% with the 10° mask and 15% with the 20° mask. Thus, even with the largest masks, perifoveal and peripheral visual information are used for coding objects' spatial location. These results indicate that peripheral vision can play a direct role in building an internal representation of objects' location in the surrounding.

56.528 **Transsaccadic memory for multiple features**

Aarlenne Khan[1](aarlennek@gmail.com), Kim YoungWook[1], Yoongoo Nam[1], Gunnar Blohm[1]; [1]Centre for Neuroscience Studies, Queen's University, Kingston, ON, Canada

Transaccadic integration refers to the integration of information across saccadic eye movements, considered to be crucial for spatial constancy. Accurate integration requires two components, 1) memorization of the object features and 2) updating of these features across eye movements, i.e. we need to remember where an object was and it's features at that location. However, not much is known about how we remember multiple features across eye movements. Here, we tested how accurately participants remembered multiple features of an object across saccadic eye movements. We asked seven subjects to compare two bars, each varying in location (1.6° left of center to 1.6°right in 0.4° intervals on the horizontal meridian), orientation (5° counterclockwise to 5° clockwise in 2° intervals) and size (1.8° to 2.3° in 0.1° increments). Both bars were viewed peripherally and sequentially with an intervening delay during which they either remained fixated or made a saccade to the opposite side. Participants reported how the second bar was different from the first for 1) all three attributes in each trial or 2) only one attribute within a block of trials. We found that remembering three attributes increased uncertainty about each attribute for all three features ($p<0.01$). Participants were most uncertain about the bar location following a saccade compared to when they remained fixated ($p<0.01$), mostly resulting from a bias in remembering the first bar to be closer to final fixation after the saccade. The intervening saccade also degraded the certainty of the orientation of the bar ($p<0.01$) and induced a reduction in the remembered size of the first bar ($p<0.05$). Based on the findings, we conclude that updating of objects across saccades introduces uncertainty in their remembered attributes. When more attributes required memorization, uncertainty increased which points towards memory interactions between different visual features and saccadic eye movements.

56.529 **Parallel attentional allocation in antisaccades**

Anna Klapetek[1](anna.klapetek@psy.lmu.de), Heiner Deubel[1]; [1]Department of Psychology, Ludwig-Maximilians-Universitaet, Munich, Germany

We investigated the allocation of spatial attention during the programming of antisaccades. The visual display consisted of a central fixation dot and two symmetrically arranged peripheral squares, one in each visual hemifield. In each trial one of the targets was briefly highlighted and participants were either instructed to shift their gaze to the cued square (prosaccade task) or to the square in the opposite hemifield (antisaccade task). After the trial they reported the orientation of a visual probe that had appeared at one of the two target locations. By probing discrimination performance at variable SOAs relative to saccade cue onset, we were able to measure the time course of attentional deployment to both target locations. An analysis of the eye movements revealed a similar pattern of results as reported in previous studies, namely longer antisaccade than prosaccade latencies and a substantial proportion of direction errors in antisaccade trials. Discrimination performance during the cue-saccade interval was analyzed both for correct antisaccades and erroneous prosaccades. The results revealed that in both cases attention was allocated in parallel to the cued location and to the correct antisaccade goal. Even before correct antisaccades, discrimination was generally better at the cued location, although this attentional bias was balanced by a rise of attention at the planned saccade endpoint immediately before the eye began to move. While the amount of attentional resources allocated to the cue location was predictive of the occurrence of erroneous prosaccades, attention at the antisaccade goal was not related to the likelihood of prosaccade errors. In conclusion, our results demonstrate parallel attentional allocation in antisaccades and support the hypothesis that the process of antisaccade programming involves the suppression of attention at the cue location.

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Spatial vision: Natural image statistics

Tuesday, May 14, 2:45 - 6:45 pm

Poster Session, Vista Ballroom

56.530 **Overestimation of the numbers of elements in a three-dimensional stimulus compared with a two-dimensional stimulus**

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Although many researchers have investigated numerosity judgments, they have tended to focus on numerosity judgments of two-dimensional (2D) stimuli. However, recently, Aida et al (2012) and Schütz (2012) suggested that the numerosity judgment of a three-dimensional (3D) stimulus has an essentially different nature from that of a 2D stimulus. We investigated whether the number of elements of a 3D stimulus (when fused, two transparent surfaces are observed in the same visual direction) would be judged as larger than those of a 2D stimulus (when fused, a single surface is observed) even when both stimuli consisted of the same number of elements. Participants' numerosity judgments in a stereoscopic space were examined in three experiments, where 2D and 3D stimuli (random-dot stereograms) were presented side-by-side on a monitor and viewed from a distance of 60 cm. In the experiments, participants completed a numerosity discrimination task, where they judged which of the two stimuli had a larger number of elements. Results showed that (1) the 3D stimulus was thought to contain more elements than the 2D stimulus, even when both had the same number of elements, (2) the amount of overestimation increased as a function of the number of elements and relative disparity between the two surfaces of the 3D stimulus, and (3) the ratio of the number of elements in the front surface to that in the back surface of the 3D stimulus had no effect on the amount of overestimation. These results indicate that overestimation in numerosity judgments occurs in stereo domains, suggesting that the visual system takes into account those elements that are possibly hidden by the front surface.

56.531 **Least squares noise in images of natural scenes is not the be all and end all**

Bhavin Sheth[1,2](brsheth@uh.edu), Jasmine Patel[3,2], Khushboo Pal[4], Ysabelle Abraham[4]; [1]Department of Electrical and Computer Engineering, University of Houston, [2]Center for Neuroengineering and Cognitive Science, University of Houston, [3]Department of Biomedical Engineering, University of Houston, [4]University of Houston

Last year (VSS, 2012), we showed that human observers of scatter plot data perceive linear regressors that minimize squared error as worse fits than regressors that minimize absolute error. Here, the perception of noise in images of natural scenes was investigated. Pictures of natural scenes were selected from www.cs.washington.edu/research/imagedatabase/groundtruth/. We introduced noise in two different but related ways: i) the total noise was distributed across all pixels of the image (distributed noise images, or Dnis), and ii) the same total noise was distributed over a quarter of all pixels (focused noise images, or Fnis); however, the total amount of noise introduced in both images was equal in a least-squares sense. The two noisy versions generated from a given image were presented side by side and remained on until the observer (n=11) chose the image that appeared subjectively clearer. If we perceive a least-squares visual world, our observers should randomly choose either image (Dni/Fni) about equally from each pair (102 image pairs total). However, there was a clear preference for Dnis (high noise Dnis: 71.3±17.0(s.d.)%) over Fnis, and the preference was amplified at the lower noise level (Dnis: 92.8±17.0(s.d.)%). Student's t-tests performed on arcsin transformed percentage values confirmed that the preference for Dnis was significant at both noise levels (high: $t(10)=6.93$, $p<0.0001$, low: $t(10)=53.4$, $p<0.0001$), and that the effect got weaker with increasing noise level ($p<0.0001$). In follow-up studies, identical total amount of absolute levels of noise will be added instead. We expect the preference for Dnis to be more muted compared with the original experiment. In order to generalize our findings across image class and perceptual task, other categories of images will be used, and observers will be asked specific questions related to the image (e.g. visual search for a specific class of object).

56.532 **Temporal whitening of retinal input during natural head-free fixation**

Michele Rucci[1,2](mrucci@bu.edu), Jonathan D. Victor[3], Murat Aytekin[1]; [1]Department of Psychology, Boston University, [2]Graduate Program in Neuroscience, Boston University, [3]Department of Neurology and Neuroscience, Weill Cornell Medical College

During natural fixation, microscopic head and eye movements keep the retinal image continually in motion. In a recent study (Kuang et al., 2012), we have shown that, during viewing of natural scenes, fixational eye movements carry out a crucial information-processing step: they remove predictable correlations in natural scenes by equalizing the spatial power of the retinal image within the frequency range of ganglion cells' peak sensitivity, a transformation, previously attributed to center-surround receptive field organization. In this previous study, to accurately record microscopic eye movements, subjects examined natural scenes with their head immobilized. Here we extend this work by examining the characteristics of the retinal input during natural head-free fixation. To this end, we used a database of previously recorded head and eye movements, collected by means of the Maryland Revolving Field Monitor, a high resolution eye-tracker which is little influenced by head translations (Steinman, 2003). Observers (N=4) looked sequentially at LED targets positioned randomly on a table in front of them, while their eye movements were recorded by means of coils, and their head position was measured by means of coils and a distance detection system. In agreement with previous reports, the image moved considerably on the retina, reaching speeds of 11 deg/sec (median 3 deg/sec), a continuous motion frequently interrupted by joint head/eye saccades. We selected periods in between saccades and estimated the spatiotemporal power spectrum of the retinal input. Results were highly similar to those previously obtained with the head immobilized. Fixational instability transformed spatial patterns of luminance into temporal modulations in a way that counterbalanced the spectral distribution of natural images and equalized the power of the retinal image over a wide range of spatial frequencies. These results further support the proposal that fixational behavior is an important component of the encoding of visual information.

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56.533 **Independence of luminance and chromatic edge orientations in natural scenes**

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Recent findings show that luminance and chromatic edge contrasts are statistically independent in natural scenes and it has been argued that a linear combination of these sources is optimal for a reliable detection of object boundaries [Hansen and Gegenfurtner 2009]. In a linear model, however, an underlying assumption is that the orientations of the luminance edges and of the chromatic edges always overlap. Here we examine the local joint statistics of chromatic and achromatic edge orientations in natural images and find a significant degree of statistical independence. Additionally, the statistical independence grows higher through the transformations of color representation from the retinal ganglion cells and LGN thalamic cells to the perceptually uniform Lab color space and its putative neural correlates. Our results provide an ecologically plausible explanation both for the non-linear color transformation from the cone-opponent space to the perceptual Lab color space as well as for recent findings of cells in the visual cortex that respond best to isoluminant-oriented patterns [Johnson et al. 2001, Bushnell et al. 2011].

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56.534 **Adaptation and visual search in medical images**

Elysse Kompaniez[1](kompaniez@aol.com), Criag K. Abbey[2,3], John M. Boone[3,4], Michael A. Webster[1]; [1]Psychology, University of Nevada, Reno, [2]Psychology, University of California, Santa Barbara, [3]Radiology, University of California, Davis, [4]Biomedical Engineering, University of California, Davis

Radiologists face the visually challenging task of detecting suspicious features within the complex and noisy backgrounds characteristic of medical images. We used a search task to examine whether salience of target features in x-ray mammograms could be enhanced by prior adaptation to the spatial structure of the images. Stimuli were 6.6 by 8.75 deg randomly selected sections from normal mammograms previously classified with BIRADS Density scores of "fatty" vs. "dense," corresponding to differences in the relative quantities of fat vs. fibroglandular tissue. The categories reflect large differences in visual texture with dense tissue appearing cloudier and more likely to obscure lesion detection. Targets were simulated tumors corresponding to bright Gaussian spots (sd = .18 deg), superimposed by adding the luminance to the background. A single target was added to each image at random locations, with contrast varied over 5 levels so that they varied from difficult to easy to detect. Reaction times were measured for detecting the target location (left or right side), before or after adapting to a gray field or random sequences of a different set of dense or fatty images (shown 4/sec for 5 min initial adapt and then 4 sec prior to each test). Observers were faster at detecting the targets in dense images after adapting to the dense structure, compared to performance for the same stimuli when instead adapted to the gray field. In contrast, adaptation to fatty images did not consistently improve reaction times. These differences could reflect differences in the relative clutter and contrast of the two image categories. For dense images, our results suggest that visual salience and search efficiency could be heightened when observers are adapted to the backgrounds they are searching on, perhaps because this adaptation allows observers to more effectively suppress the structure of the background.

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56.535 **Local image statistics: A highly conserved perceptual space encompassing statistics of low and high order**

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Processing of local correlations is crucial to early vision, as it underlies identification of lines, edges, and texture. In natural scenes, correlations of low and high order are intertwined in a complex fashion. Here we extend an order-by-order analysis of sensitivity to image statistics to these complex combinations. To reduce dimensionality, we consider only configurations of binary pixels in 2x2 neighborhoods, as this captures informative local image statistics (Tkacik et al., 2010). The 16=2(2x2) configurations of binary pixels within this neighborhood correspond to 10 independent image statistics, of orders 1 to 4. In four subjects, we used a segmentation task to characterize sensitivity to these 10 image statistics, alone and in pairwise combinations. A perceptual metric with ellipsoidal iso-discrimination contours provides an accurate synopsis (~5% RMSE) of each subject's sensitivities. Further, psychophysical data respect the symmetries of the checkerboard lattice: sensitivity to an image statistic is unchanged (within ~10%) following lattice rotations or reflections. These observations enable a decomposition of the 10-d space according to spatial symmetries. There is a 5-dimensional subspace comprising statistics of all orders, each of which is invariant under spatial rotations and reflections. This contains 5 of the ellipsoid's principal axes; across subjects, axis directions agree within ~5%, and relative axis lengths agree within ~20%. There is a 2-dimensional subspace of statistics, each of which is sign-inverted by cardinal reflections. This contains 2 principal axes, with similar consistency across subjects. One of these axes is predicted to be metameric to random; this is supported by preliminary data. The last 3 principal directions correspond to other symmetries, and necessarily agree exactly across subjects. In sum, perception of local image statistics is highly conserved across subjects, and a Euclidean model built on an order-by-order analysis predicts, at least qualitatively, perception of complex combinations of image statistics.

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56.536 **Perceptual salience of fourth-order visual textures and natural scene statistics** John Briguglio[1](johnbri@sas.upenn.edu), Ann Hermundstad[1], Mary Conte[2], Jonathan Victor[2], Gasper Tkacik[3], Vijay Balasubramanian[1]; [1]Department of Physics and Astronomy, University of Pennsylvania, [2]Weill Medical College of Cornell University, [3]Institute of Science and Technology, Austria

The statistical regularities of natural signals are a starting point for understanding the characteristics of early visual processing, e.g. the center-surround architecture of retinal ganglion cell receptive fields. Can this matching between natural signal statistics and neural processing mechanisms be extended beyond the sensory periphery? Our recent work (Tkacik et al., 2010) showed that human sensitivity to isodipole (fourth-order correlated) synthetic textures, known to arise in cortex, is closely related to the structure of fourth-order spatial correlations in natural scenes. This leads us to propose a specific organizing principle: The perceptual salience of visual textures increases with the variance (i.e. unpredictability) of the corresponding correlations over the ensemble of natural scenes. To test this idea we focused on local image statistics: correlations between two, three, and four adjacent pixels within a 2x2 square. For binarized images, there are four pairwise correlations -- vertical (betaV), horizontal (betaH) and diagonal (beta,beta/) -- four third-order correlations (theta1,2,3,4) and one fourth-order correlation (alpha). We measured these correlations in a large ensemble of image patches taken from the UPenn Natural-Image Database. The variance in these correlations over the ensemble was robustly ordered (increasingly) as: Var(theta1,2,3,4),Var(alpha),Var(beta-Diag), Var(betaV,H). Thus, our broad hypothesis predicted the same ordering of perceptual salience of artificial textures with correlations of different types. Furthermore, our hypothesis predicts that the principal components of the covariance of these correlations in natural scenes match the principal components of observers' perceptual sensitivities to synthetic textures. These predictions are confirmed in psychophysical experiments: observers' ability to use image statistics to segment artificial visual textures conformed to the ordering of their variances in natural images, and observers' principal axes of sensitivity lie near the principal axes of covariances of the image statistics. Our results suggest central neural mechanisms are efficiently tuned to the statistics of natural scenes.

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56.537 **Does V1 primarily encodes Spatial Frequencies or Features?** Simon Clavagnier[1](simon.clavagnier@mcgill.ca), Reza Farivar-Mohseni[1], Bruce C Hansen[2], Robert F Hess[1]; [1]McGill Vision Research, McGill University, Canada, [2]Colgate University, Hamilton, NewYork

t is now well-accepted that neurons in V1 cortical area are affected by visual information outside of their classic receptive fields. Recently it has been proposed that V1 neurons may differentiate between meaningful structures in an image as opposed to noise. If V1 neurons are indeed responsive not only to the spatial frequency content of an image but also to its structure, then a manipulation that maintains the spatial frequency content but disrupts image features should differentially affect V1. We mapped the fMRI V1 responses of volunteers while they were watching a high-resolution continuous video of natural scenes. The structure of that video was modulated in band-selective phase scrambling, whereby the phase values corresponding to the spatial frequency content in a band were maintained while outside of the band, they were scrambled. Eccentricity maps were used as topographical references. We found that despite the identical spatial frequency content in the movie, V1 responses were selective for phased-aligned content, and diverting attention did not affect the pattern of responses. But filtering the movie such so as to preserve one frequency band with scrambled phase values did not have a similar response. The results suggested that the pattern of activity in V1 area is reorganized depending if the spatial frequency content of an image give rise to perceptually relevant structure or not.

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56.538 **Preference for higher-order luminance regularities in natural scenes** Daniel Graham[1](graham@hws.edu), Bianca Schwarz[2], Anjan Chatterjee[3], Helmut Leder[1]; [1]Department of Psychology, Hobart and William Smith Colleges, [2]Department of Psychological Basic Research, Faculty of Psychology, University of Vienna, [3]Department of Neurology, University of Pennsylvania School of Medicine

The distribution of luminances in natural scenes varies greatly depending on lighting, material properties, and other factors, but some luminance statistics—particularly higher-order statistics—appear to be regular. Natural scene luminance distributions typically have positive skew, and for single objects, there is evidence that higher skew is a correlate (but not a guarantee) of glossiness. Skewness is also relevant to aesthetics: it is a good predictor of fruit freshness, and preference for glossy single objects (with high skew) has been shown even in infants. Given that primate vision appears to efficiently encode natural scene luminance variation, and given evidence that natural scene regularities may be a prerequisite for aesthetic perception in the spatial domain, here we ask whether humans in general prefer natural scenes with more positively skewed luminance distributions. If humans generally prefer images with the higher-order regularities typical of natural scenes and shiny objects, we would expect this to be the case. By manipulating luminance distribution skewness (holding mean and variance constant) for individual natural images, we show that in fact preference varies inversely with skewness. This finding holds for both artistic landscape images and images from natural scene databases, including scenes with and without glossy surfaces, as well as for noise images. Across these conditions, humans prefer images with skew near zero over higher positive skew images. These results suggest that humans prefer images with luminances that are distributed relatively evenly about the mean luminance, or images with similar amounts of light and dark. Following evidence from prior brain imaging studies, we propose that human preference for higher-order statistical regularities reflects an efficient processing advantage of low-skew images over high-skew images. We further propose that human artwork generally possesses low skew luminance histograms in part as a way to achieve efficient visual processing.

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56.539 **Eccentricity-dependent sensitivity loss of amplitude spectrum slope discrimination.** Aaron Johnson[1](aaron.johnson@concordia.ca), Bruno Richard[1], Dave Ellemberg[2], Bruce Hansen[3]; [1]Dept. Psychology, Concordia University, Montréal, Canada., [2]Dept. Kinesiology, University of Montreal, Montréal, Canada., [3]Dept. Psychology & Neuroscience Program, Colgate University

Natural scenes exhibit much statistical regularity. Perhaps the most explored regularity is the association between spatial frequency (f) and the amplitude of each spatial frequency component (i.e., their second-order statistics). This association is present in virtually all natural scenes and follows the general form: amplitude = $1/f^{\alpha}$, with the slope (α) commonly being between 0.6 and 1.6. Although researchers have shown that humans are sensitive to changes in the slope, these studies have measured sensitivity at (or near) the fovea only. Sensitivity to visual acuity and contrast decreases as eccentricity from the fovea is increased, and this eccentricity-dependent loss in sensitivity may affect the ability to detect changes in the amplitude spectrum slope. Participants were presented a series of broadband noise stimuli with different amplitude spectrum slopes (α = 0.4, 0.6, 0.8, 1, 1.2, & 1.4) at various eccentricities (0, 0.5, 1, 2, 4, & 8 degrees) by means of a gaze-contingent multi-resolution display (GCMRD) 2-IFC. The GCMRD presents the un-altered amplitude slope value at fixation, and in one of the intervals, presents a peripheral image for which the slope is changed. Thresholds were calculated with a Psi adaptive threshold method. For foveal and parafoveal conditions (<1 degree), our results replicated previous findings. Thresholds where the lowest when the slope of the amplitude spectrum was 1.2 and 1.4, while they were highest for slopes of 0.6 and 0.8. However, all thresholds increased for eccentricities greater than 1 degree. The rise in threshold was the greatest for amplitudes that ranged from 0.4 to 1, and the least for amplitude slope values greater than 1. We interpret these data such that the eccentricity dependent sensitive loss in amplitude spectrum slope discrimination is due to the lower and more limited range of spatial frequencies available to encode the amplitude spectrum at greater eccentricities.

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56.540 **Size dependent increase in sensitivity to the slope of the amplitude spectrum is not solely dependent on the increased low spatial frequency representation of larger stimuli.** Bruno Richard[1](brichard21@gmail.com), Bruce Hansen[2], Dave Ellemberg[3], Aaron Johnson[1]; [1]Department of Psychology, Concordia University, Montréal, Québec, Canada., [2]Dept. Psychology & Neuroscience Program, Colgate University, [3]Dept. Kinesiology, University of Montréal, Canada.

We have previously investigated if threshold discrepancies between studies that have measured sensitivity to the slope of the amplitude spectrum may be due to differences between stimulus size (Richard et al., VSS 2012). We found that slope discrimination thresholds decreased as stimulus size increased, and concluded that the decrease in thresholds might be due to either the greater spatial summation of contrast in the larger stimuli, or the additional lower spatial frequencies present in larger stimuli. Here, we investigated if the latter can explain the size dependent increase in sensitivity to an amplitude spectrum slope. We used the largest stimulus size from the previous study (11.3°) containing the largest range of spatial frequencies (0.09 – 13.4 cpd), and filtered it with an ideal high-pass filter to mimic the spatial frequency content of smaller stimuli. The stimulus covered approximately 7 octaves (0.09-0.18, 0.18-0.35, 0.35-0.71, 0.71-1.42, 1.42-2.84, 2.84-5.68,5.68-11.36 cpd), and we used 6 high-pass filters (cut-off frequencies 0.12, 0.25, 0.50, 1.00, 2.00, 4.02 cpd). Thresholds did increase as higher spatial frequencies were removed from the stimulus, which indicates lower thresholds are somewhat dependent on the lower spatial frequencies present within larger stimuli. Yet, this increase did not match the decrease in threshold found in the previous study. Our results show that a minimum of three octaves - which represent a stimulus size of about 2° - was required for thresholds to begin increasing. When more than three octaves were present, thresholds remained relatively stable. Slope discrimination is influenced by spatial frequency content of the stimuli, but this does not completely explain the size effect found in the previous study. Therefore, we conclude that spatial summation of contrast may also contribute to the decrease in thresholds found when stimulus size is increased.

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56.541 **Optimal Contour Interpolation Using Natural Scene Statistics** Anthony D. D'Antona[1](anthonydantona@gmail.com), Wilson S. Geisler[1]; [1]Center for Perceptual Systems and Department of Psychology, University of Texas at Austin

Retinal images are two-dimensional projections of three-dimensional scenes, and therefore the contours of many objects in a scene are partially occluded. Contour occlusions create two difficult tasks for visual systems: 1) determining which visible contour elements belong to the same object (contour grouping and contour integration), and 2) determining the shapes of contours between visible contour elements (contour interpolation). Here, we focus on contour interpolation. Given two spatially separated contour elements with known orientations, we use the statistics of contours in natural scenes to determine the optimal estimate of the contour shape connecting these elements. Contour data was sampled from a database of natural image contours. Each contour was rotated and scaled into common coordinates, and then resampled to a fixed number of points. These standardized contours were binned by the orientations of the two end contour elements. For each bin, principle component analysis (PCA) was performed on every contour within that bin. For almost every bin, the first three principal components accounted for over 90% of the variance. All contours in a given bin were projected onto these first three components, resulting in a 3D cloud of PCA coefficients representing the shapes of all the contours in that bin. In this PCA representation, the centroid of the distribution of PCA coefficients specifies the Bayesian optimal (minimum mean squared error) estimate of contour shape. These statistics characterize the information present in natural images for determining contour shape using only local, spatially separated contour elements. Our results provide principled predictions for interpreting the results of previous contour interpolation studies and future experiments. Importantly, we find that contour shapes in natural images (excluding long contours containing sharp changes in orientation) are well characterized by only three dimensions, once the orientations at the two ends of the contour are specified.

Acknowledgement: EY 02688

56.542 **Painting What We See: Painters Over-Regularize Structure in the Environment** April Schweinhart[1](amschw05@louisville.edu), Edward Essock[1,2]; [1]Department of Psychological and Brain Sciences, University of Louisville, [2]Department of Ophthalmology and Visual Science, University of Louisville

We have recently investigated the relationship between the statistical properties of art images and biases in visual perception with a variety of manipulations (Schweinhart, Kim, & Essock, JOV 2011; Schweinhart, Williams, Dubinchik, O'Keefe, & Essock JOV 2012; Schweinhart & Essock, Perception 2012). These investigations are based on the supposition that when an artist paints a scene, we might expect it to contain the same structural regularities found in natural images in order to look "right" to the viewer. It is well documented that artworks contain the same regularities of scale (a spatial frequency fall-off of 1/frequency) as natural scenes (e.g., Simoncelli & Olhausen, Annu. Rev. Neurosci. 2001; Graham & Field, Perception, 2008; Graham, Friedenberg, & Rockmore, VisCog 2010). In our work, we investigate the presence in art images of another regularity of typical natural scenes-- on average, scenes contain a "horizontal effect" pattern of content: most content at horizontal and least at the obliques (Hansen & Essock, JOV 2004). Surprisingly, we find that artists actually over-emphasize the typical natural regularities in their paintings, particularly of orientation.. In average natural scenes, the anisotropy diminishes with increasing spatial frequency, but in paintings, the typical anisotropy is present at all spatial scales. Here we present findings from three projects: comparing museum paintings of landscape and portraits to photographs of faces and natural scenes; comparing paintings to photos of the actual scene painted; and a set of commissioned paintings completed under controlled conditions. All of these painting types indicate over-regularization in the representation of orientation. We suggest that this over-regularization is due to anisotropic suppression in the visual system that whitens the physical anisotropy and that artists capitalize on this in their artworks. In addition, we consider methods to remedy the problem of unequal sampling across orientations at low spatial frequencies in a FFT.

56.543 **Aesthetic Judgment of Texture Patterns: Beauty is in the Perceived Density of the Beholder.** Jay Friedenberg[1](jay.friedenberg@manhattan.edu), Ashley Wasilewski[1], Erin Donahue[1]; [1]Psychology Department, Manhattan College

Most research on texture perception has focused on segmentation and classification. Recent efforts however are now underway to investigate human affective interpretation and construction of predictive computational models (Kim et. al., 2006; Thumfart, et. al., 2012). Much of this work has attempted to explain how lower-order statistics get mapped onto higher-order psychological variables. In the current study we manipulate a very basic texture property, namely density, to examine its effect on aesthetic judgment. Our patterns were generated using a square grid. Individual squares in this grid could either be filled in as black or unfilled and left white. There were ten different density conditions, ranging from a 0.1 occupation probability (10% of the cells were filled randomly) to a 1.0 cell occupation probability (all cells filled). Participants rated each pattern in terms of their perceived attractiveness using a seven-point scale. In a second experiment we manipulated the shape of the density function, varying the drop in fill probability from the center of the grid outwards. In the first experiment there was a statistically significant effect of density $F(9, 216) = 65.7$, $p < 0.1$. Average attractiveness ratings increased as density increased, peaking at a 0.7 occupation probability. Participants preferred more dense patterns in experiment two $t(35) = 4.9$, $p < 0.5$. Those with less dispersion, i.e., with a higher slope value for the density function, were ranked as significantly more attractive. The results are interpreted according to an "edge of chaos" model where peak attraction occurs near the border between patterns that are ordered and those that are chaotic. Many complex systems in nature exist in this regime and preference for patterns of this sort may reflect an innate propensity toward naturalistic stimuli.

Visual search: Attention

Tuesday, May 14, 2:45 - 6:45 pm

Poster Session, Vista Ballroom

56.544 **The effects of grouping search elements by depth on target selection** Nonie Finlayson[1](nonie.j@gmail.com), Roger Remington[1], James Retell[1], Philip Grove[1]; [1]Schoolf of Psychology, The University of Queensland

Previous research has shown that while the number of elements in a search display affects the time to find a target, search can be more efficient if targets contain a unique feature, such as a particular colour, that can either be detected in parallel or can be used to confine search to elements with that property (Egeth, Virzi, & Garbart, 1984). Our study examined whether the effects of distracting elements could be similarly reduced by segmenting a conjunction search across two depth planes. Three important empirical findings emerged. First, we found evidence for parallel search

when the target was a feature singleton on one depth plane, but a conjunction search given distractors on the non-target plane. This result indicates that parallel search is possible on an attended depth plane. Second, benefits of segmentation in depth were only observed when the target depth plane was known in advance. This result indicates that, unlike colour, segmentation in depth does not afford parallel access to information on separate depth planes. Third, no benefit of segmentation in depth was observed when both depth planes required serial search. This result can be accounted for by assuming that the act of attending to a depth plane draws on the same attentional processes required for serial search within a depth plane. We conclude that segmentation into two depth planes can facilitate visual search, but unlike colour or other elementary properties, does not provide an automatic, pre-attentive segmentation.

56.545 **Attentional salience as a function of visual statistical properties: A visual search study** Natalia Tiurina[1](natalyatyurina@gmail.com), Igor Utochkin[1]; [1]The National Research University "Higher School of Economics", Russia

Research of the past decade has shown that many features of multiple objects can be efficiently represented as summary statistics, e.g. average size. Statistical properties are supposed being hierarchical features affecting global similarity and the perceived properties of individual objects (Ariely, 2001; Brady & Alvarez, 2011). They presumably can affect, therefore, the property known as salience, an ability of visual singleton to capture attention in bottom-up fashion. We tested this hypothesis in 4 visual search experiments. We proposed that the salience should increase with the distance from ensemble average defining global similarity. We also proposed that salience is affected by local similarity defined by the number of items closest to a target by critical dimension. Observers searched for a size target among 13 or 25 items of four different sizes. 3 target sizes were intermediate between adjacent distractor sizes, 2 other targets were outside distractors size distribution, close to smallest and largest distractors. A target between 2nd and 3rd distractor sizes was an average, a most globally similar target. In Experiments 1 and 2 observers searched for an odd size target either in sets with normally (Exp. 1), or bimodally (Exp. 2) distributed sizes. The distribution shapes allowed testing local similarity effects as a function of number of adjacent distractors. We found in the result that within distractors distribution search efficiency didn't depended on global or local similarity; it depended solely on absolute size demonstrating typical size search asymmetry. Outside targets were, however, much better detectable. In Experiments 3 and 4, observers searched for a known size targets, and results were substantially the same. Hence, both global and local similarities appear to have no effect on target salience within items distribution, perhaps, due to noisy interactions insufficient for representing individuals. However, boundary targets gain greater salience, perhaps, because of being treated as outliers.

Acknowledgement: The study is supported by a RFBR grant: 12-06-31223

56.546 **Transition features facilitate visual search in heterogeneous displays** Maria Yurevich[1](yurevichm@ya.ru), Igor Utochkin[1]; [1]National Research University - Higher School of Economics

Effects of display heterogeneity on visual search efficiency are well documented (Duncan & Humphreys, 1989). Even when searching a clearly distinguishable feature singleton, attentional salience falls down with heterogeneity of distractors (e.g., Santhi & Reeves, 2004). It is presumed that the visual system is able to preattentively separate heterogeneous features to homogenous subsets and attend each subset serially to find a singleton. The issue we addressed in our study was as follows: How does the visual system process heterogeneous sets that can't be clearly distinguished? Theoretically, it should conjoin all heterogeneous items under the same subset representation and a singleton, therefore, would become more salient despite large heterogeneity. In our visual search task observers searched for an odd-sized target (either small, or large) among 13, 25, or 37 differently sized items. There were two homogenous conditions: (1) all distractors were of medium or (2) opposite size (e.g., large distractors with small targets and vice versa). Above, two heterogenous conditions were tested. In one such conditions all distractors were of (3) medium and opposite sizes (the difference between medium and each opposite size were clearly distinguishable). Finally, in condition (4) four transition sizes filled the gap between medium and opposite distractors providing six heterogeneous sizes. We found in the result near parallel pattern of search performance in all positive conditions. The fastest detection was predictably found for homogenous displays with opposite sizes. The slowest detection was found for two distinct sizes of distractors. The intermediate efficiency was found for both medium homogenous and heterogeneous sets with transition sizes. RTs were substantially the same in these two conditions. This suggests that the visual system does fail to separate such transitional sets to subsets and treat them as a unitary perceptual entity opposing to a singleton (despite large heterogeneity and wide range of differences).

Acknowledgement: Study was implemented within the Programme for basic research of the Higher School of Economics in 2012

56.547 **Collinear contour integration impairs visual search before binocular fusion** Hiu Mei Chow[1](dorischm@gmail.com), Chia-huei Tseng[1]; [1]Department of Psychology, The University of Hong Kong

Perceptual grouping plays an indispensable role on figure/ground segregation and attention distribution. However, its relation with visual attention is not well understood yet. Jingling & Tseng (2012) reported that visual search was harder when the target overlapped with a global distractor constituted by collinear elements but not by non-collinear elements. The present study aims at investigating how early this collinear grouping affects selective search in visual pathway. Our observers viewed a 9x9 search display containing identical vertical (or horizontal) bars except a randomly selected distractor column consisting of orthogonal bars. This distractor was grouped into a collinear (snake-like) or non-collinear (ladder-like) organization. Participants judged orientation of a target located either on the distractor column or the other columns. In Experiment 1, we varied the distractor length (= 1, 5, or 9 bars) and found search impairment occurred only at the visual display when the collinear distractor reached a critical length (= 5 bars), not under or when distractor is non-collinear. In Experiment 2, we used a stereoscope to split the distractor column into two eyes: one eye saw a distractor column with varied length (distractor_length_mono = 1, 5, or 9 bars) while the other eye saw the rest parts of the distractor. When both eyes were properly fused, observers saw a search display identical to Experiment 1 with the longest distractor length (distractor_length_bino = 9 bars). If collinear contour affected visual search after binocular fusion, the search impairment effect should be observable in all three conditions. However, we found that observers' RTs were identical to that in Experiment 1, suggesting monocular collinear contour information dictated selective attention. Our results imply that the effect of collinear grouping on attention is likely to be driven by bottom-up processes.

56.548 **Abolition of Asymmetry: the Impact of Pre-task on Visual Search** Emily S. Cramer[1](ecramer@interchange.ubc.ca), Ronald A. Rensink[1]; [1]University of British Columbia

Visual search has often been assumed to be unaffected by tasks prior to search. However, we find that certain pre-tasks can abolish certain visual search asymmetries, making search equally inefficient for both types of target. To investigate this "abolition of Asymmetry" (AOA), two conditions were compared. In the first, 11 participants searched for a target defined by length. In the second, search was the same but was preceded by an object recognition (OR) task (Chua, Boland and Nisbett, 2005), which presented participants with a series of images and then probed their recollection of the images' features. Observers not given a pre-task showed a strong asymmetry: 34.9ms/item for long targets vs 51.3 ms/item for short ones. However, when administered the pre-task, search rates became symmetric: 47.5 ms/item for long targets vs 50.3 ms/item for short ones. A possible explanation for this abolition is that the OR task induces a holistic style of visual processing, similar to that found in East Asian observers, who also show no asymmetries in search (Ueda et al., in preparation). To test this explanation, we conducted four further conditions. In the first we decreased the motivation for holistic processing by decreasing the size of the images in the OR Task. Symmetry was still abolished. In the second, we used the original pre-task, but imposed a frame over the search display. Both circular and square frames reinstated asymmetry, with the circle reinstating a slight (52.1ms/item to 40.8ms/item) and the square a strong (59.2ms/item to 42.1ms/item) asymmetry. In the last conditions, we examined two other types of visual search, replacing search for length with search for contrast and for a Q among O-shaped items. Both asymmetries survived the pre-task: as such, the pre-task appears to abolish asymmetry for only certain kinds of feature.

Acknowledgement: Natural Sciences and Engineering Council, Canada

56.549 **Visual search for chasing objects among distractors** Hauke Meyerhoff[1](h.meyerhoff@iwm-kmrc.de), Markus Huff[2], Stephan Schwan[1]; [1]Knowledge Media Research Center, Tuebingen, Germany, [2]University of Tuebingen, Germany

For decades, anthropomorphic interactions (e.g., chasing, fighting, etc.) between two or more objects have been an important tool to study perceptual animacy (Scholl & Tremoulet, 2000, TiCS). Recent research revealed that differently salient chases induce animate impressions parametrically and that these impressions can be measured psychophysically (Gao et

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al., 2009, Cognitive Psychology). These prerequisites allowed studying the link between perceptual animacy and visual attention. This line of research demonstrated that chasing objects do not arise effortlessly out of displays including distractors. Instead, an effortful visual search is necessary to detect chasing objects (Meyerhoff et al., in press, JEP:HPP). However, there are no distinctive visual cues on chasing objects that might guide attention during chasing detection. Therefore, the current set of experiments explores several variants of the chasing detection paradigm in order to investigate how human observers search for a chase among distractors. In Experiment 1, we investigate whether participants search for cues suggesting the presence or absence of a chase. Our results suggest that observers search for cues suggesting the presence of a chase because participants are faster in detecting a chase among non-chases than vice versa. In Experiment 2, we demonstrate that inter-object spacing is a powerful cue indicating the presence of a chase because chasing detection latencies decrease with decreasing inter-object spacing. Finally, Experiments 3 and 4 investigate whether participants search for a pair of chasing objects or for an individual object that is involved in a chase. Our results indicate that participants are faster in detecting chasing objects than objects being chased. Furthermore, a linear increase in response latencies with the number of objects in the display suggests that participants search for individual objects. In sum, our experiments suggest that observers search for one object that is approaching another object during chasing detection.

56.550 **The Statistical Saliency Model can choose colors for items on map displays** Joshua Shive[1](jshive@tnstate.edu), Sharra Rosichan[2], Sherika Austin[1], Christena Wade[1]; [1]Department of Psychology, College of Education, Tennessee State University, [2]Department of Psychology, College of Behavioral and Health Sciences, Middle Tennessee State University

When a display is cluttered, drawing attention to specific display items may be difficult. Our current project examines how to choose distinctive (i.e., salient) colors for items on high-clutter and low-clutter maps using predictions of a model of visual search. Thirty observers rated the degree of clutter on each of 150 MapQuest maps containing symbols representing colored location pushpins. We calculated the average clutter rating for each map and identified 20 high-clutter maps and 20 low-clutter maps. Next, the Statistical Saliency Model (Rosenholtz et al., 2007) was used to choose colors for pushpins on each of the 20 high-clutter and 20 low-clutter maps. For each map, we calculated the model-predicted salience of a pushpin added to the map, given different potential pushpin colors (the 267 colors in the ISCC-NBS standard color system). We chose the color with maximum predicted salience. For comparison, we also created maps where the pushpins were assigned the color with minimum predicted salience or median predicted salience. We followed this procedure for all 40 maps, resulting in a set of 120 maps. We validated the color assignments in a visual search experiment where observers were shown a pushpin and then asked to search for it on a map. Maximum predicted salience pushpins were found faster than pushpins of other colors on both high- and low-clutter maps, indicating that our approach can choose colors for display items to facilitate search.

56.551 **Stimulus context controls the speed of attentional spotlight shifts in human visual cortex** Thomas Töllner[1](thomas.toellner@psy.lmu.de), Markus Conci[1], Hermann J. Müller[1,2]; [1]Department of Psychology, Ludwig-Maximilians-Universität München, [2]School of Psychological Sciences, Birkbeck College London, University of London

When humans or other primates search their environment for target objects critical for achieving their current action goals, the times they take to react upon the intended object are generally the faster the more the target differs from the objects in its vicinity. Moreover, if the physical distinctiveness of a given object from its surround exceeds a certain threshold, it might even force the searcher to attend to its location in an automatic, involuntary manner. Here, we provide an electroencephalographic signature of the similarity between a target stimulus and its surrounding context in the human visual cortex. By coupling millisecond-by-millisecond scalp-recorded voltage fluctuations to mental chronometry data during two illusory-figure search tasks, we observed a gradual decrease in internal focal-attentional selection times (as indexed by the Posterior-Contralateral-Negativity) to be correlated with external behavioural response latencies, the more relative to less an invariant target was distinguishable from its surround. Additionally, for targets of high, but not intermediate and low, salience, we found these context-driven effects even more cortically amplified if participants were provided with pre-knowledge regarding the physical context of the upcoming target stimulus. These results provide a challenge to traditional models of visual-selective attention and/or perceptual decision-making which envisage focal-attentional selection being mediated by internal templates that operate exclusively on target-defining feature coding. Instead, we provide direct neurophysiological evidence for a saliency-based processing architecture underlying the human visual system, in which the outcome of top-down accessible, pre-attentive feature-contrast computations determines when and where we engage our spotlight of attention.

Acknowledgement: This research was supported by German Research Foundation (DFG) grant (Nr. CO 1002/1-1).

56.552 **Searching for single or multiple exemplars and categories: Electrophysiological markers of category-based attentional guidance** Rachel Wu[1](rachelwu2006@gmail.com), Rebecca Nako[2], Gaia Scerif[3], Martin Eimer[2]; [1]Brain and Cognitive Sciences, University of Rochester, [2]Department of Psychological Sciences, Birkbeck, University of London, [3]Department of Experimental Psychology, University of Oxford

Visual search is often guided by top-down attentional templates that specify target-defining features. But search can also occur at the level of multiple objects or categories. With adults, we measured the N2pc component, an event-related potential (ERP) marker of attentional target selection in two visual search experiments where targets were defined as either one item (e.g., the letter C), multiple items (e.g., the letters C, F, and X), or categorically (e.g., any letter). Experiment 1 encouraged category-based selection by consistently presenting targets among distractors from a different category (e.g., numbers). Reaction times (RTs) were fastest and the N2pc largest during search for a single item, demonstrating that target selection is most efficient when it is guided by a feature-specific template. There were no RT and N2pc differences between the category-based search task and search for two or three items in Experiment 1, indicating that category-defined templates were used in all three tasks. In Experiment 2, a category-based search strategy was not available because letter targets were now presented among letter distractors. Search efficiency decreased as the number of candidate target letters increased, suggesting that within-category search was based on multiple templates for each target. Results demonstrate that category-based search can operate at early visual stages, and that it is more efficient than within-category search for multiple targets, but less efficient than feature-guided search.

Acknowledgement: This research was funded by a British Academy grant (SG-110780)

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Wednesday Morning Talks

Visual search

Wednesday, May 15, 8:15 - 9:45 am

Talk Session, Royal Ballroom 1-3

Moderator: Todd Horowitz

61.11, *8:15 am*

Visual foraging: Quitting behavior when searching aerial maps follows the Marginal Value Theorem Todd Horowitz[1](todd.horowitz@nih.gov), Kilian Semmelmann[2,3], Sage Boettcher[3], Jeremy M Wolfe[3,4]; [1]Basic Biobehavioral and Psychological Sciences Branch, National Cancer Institute, [2]Department of Psychology, Ludwig-Maximilians-Universität München, [3]Visual Attention Laboratory, Brigham and Women's Hospital, [4]Department of Ophthalmology, Harvard Medical School

Consider a radiologist searching a mammogram for tumors, a baggage screener searching for weapons, or an intelligence analyst poring over satellite imagery of North Korea. In each of these visual search tasks, each image contains an unknown number of targets and there are many images to get through. How do observers choose when to move to the next image? These tasks can be thought of as foraging tasks, which have been extensively studied in behavioral ecology. According to the Marginal Value Theorem (MVT), an organism leaves a patch when the local rate of acquiring energy drops below the global rate. Here we test whether MVT applies to a novel visual map foraging task. Stimuli were 50 maps sampled from ten major US metropolitan areas. From each metropolitan area, we selected five 3.4 square km images ranging from dense downtowns to sparse rural areas. Observers (N = 29) searched maps for gas stations using a custom interface created via the Google Maps API, allowing them to zoom in and out as well as pan around map images. Observers were given 50 minutes to find as many gas stations as possible. Our primary finding was that observers' patch-leaving (i.e., map-leaving) strategy was well-described by MVT. The instantaneous reward rate for the last gas station located on a map was approximately the average global reward rate for that observer. Second, we found that observers were more likely to miss gas stations in maps that had more of them, independent of literal "crowding" by urban density. This may reflect "satisfaction of search". Third, we identified three within-patch search strategies: "knowledge-based" (e.g., searching along major thoroughfares); systematic "scanning" (e.g., searching along a grid); and "random sampling". Knowledge-based strategies were most successful. Interestingly, use of the knowledge-based strategy declined with age.

Acknowledgement: Google

61.12, *8:30 am*

Tortoise or hare? Picture-derived target "templates" quicken search but are prone to decay. Word-derived templates slow search, but are stable over time. Michael Hout[1](michael.hout@asu.edu), Stephen Goldinger[1]; [1]Department of Psychology, Arizona State University

When people look for things in their environment, they seldom have perfect knowledge regarding the appearance of the to-be-located item. Rather, target "templates" – the mental representations used to guide attention toward targets – vary in their precision, as when looking for your favorite pen, versus any pen at all. We compared visual search performance when target templates were cued by pictures of the items, relative to categorical labels of the targets (i.e., "find a pen"). We examined reaction time, and used a signal detection framework to assess sensitivity (i.e., how well targets were detected) and response bias (how likely people were to respond "present") during search. Participants searched for the same target (or targets) up to four times; target identities were new for each search "block". On each search, participants indicated the presence or absence of the target(s), and then quickly searched again if no targets appeared. Half the participants received reminder cues after each search, to "refresh" their templates. Occasionally, four consecutive target-absent searches were presented. Consistent with prior research, picture cues elicited superior performance: Sensitivity was high, and RTs were fast, relative to search using word cues. However, word cues produced stable performance over time. When people search repeatedly using a picture cue (without reminders after each search), RTs on target-present displays are slowed. Moreover, sensitivity decreases without periodic "refreshing", and this effect is exacerbated when searching for multiple targets. By contrast, although search using word cues is slower overall (and less sensitive), reminders are unnecessary to refresh the target template. A lack of reminders does not hinder performance, nor does it exacerbate the effect of target "load." These results suggest that pictorial templates may guide attention efficiently, but they are prone to decay over time, a caveat that is not shared by categorical templates.

61.13, *8:45 am*

Conjunction-guided selection in visual search Igor Utochkin[1](isutochkin@inbox.ru); [1]The National Research University "Higher School of Economics", Russia

Models of attentional guidance suggest that the visual system can split heterogeneous items to homogenous subsets and inspect subsets separately. It is implied, however, that this subsets segmentation is based predominantly on preattentive feature selection. As features are unbound at preattentive level, the visual system has no "knowledge" of conjunctions heterogeneity (Treisman, 2006). Four experiments demonstrate that the information about conjunctions is globally available and affects attentional deployment during search. In Experiments 1 and 2, observers searched for orientation×color conjunctions either in variable, or in consistent mapping conditions. The number of concurrently presented distracting conjunctions was 2 or 3 while the alphabet of features remained constant. Proportions of features were manipulated to dissociate between feature- and conjunction-based segmentation strategies. The results suggest that conjunctions can be used for segmentation along with features. In Experiments 3 and 4, observers searched the same orientation×color conjunctions among 2 other distracting conjunctions sharing either color, or orientation with a target. An irrelevant size dimension was added so that (1) all items were the same in size; (2) size completely correlated with other features (congruent condition) making conjunction subsets even more distinguishable; (3) size was orthogonal to other features (incongruent condition) multiplying the number of conjunctive subsets. In both variable and consistent search tasks, congruent displays provided the most efficient search that can be ascribed to redundancy gain. Incongruent condition yielded the most inefficient search. The results correspond to the classical Garnerian pattern of integrality (Garner & Felfoldy, 1970) suggesting global representation of conjunctions rather than separate features. The overall conclusion contradicts purely preattentive framework of subset segmentation. However, it is consistent with the notion of broadly distributed attention (Treisman, 2006) that somehow binds features but fails to locate particular conjunctions and estimate their proportion precisely. However, it can subsequently guide focused attention.

Acknowledgement: The study was implemented within the Programme for basic research of the Higher School of Economics in 2012

61.14, *9:00 am*

Visuotopic mapping of the parietal cortex distinguishes areas involved in synesthetic feature binding Summer Sheremata[1,2](ssheremata@berkeley.edu), Bryan Alvarez[3,4], Luis Zertuche[5], Michael Silver[1,2], Lynn Robertson[1,3,4]; [1]Helen Wills Neuroscience Institute, University of California, Berkeley, [2]School of Optometry, University of California, Berkeley, [3]Department of Psychology, University of California, Berkeley, [4]Veteran's Administration, Martinez, USA, [5]Olin Neuropsychiatry Research Center Hartford Hospital

Although we experience a unified perceptual world, the binding of features into integrated percepts is a complex neural process. Synesthesia, a condition in which one stimulus feature (e.g., letters) elicits the consistent experience of a second feature (e.g., color), has been argued to be an example of hyperbinding (Robertson, 2003), and it occurs within otherwise neurologically normal populations. Thus, identification of brain areas activated during synesthetic binding may lead to a better understanding of the neural processes involved in feature binding. Previous work has implicated a number of different parietal cortical areas in feature binding and synesthesia. However, within the parietal cortex, the spatial location of functional areas is highly variable across subjects. We therefore used region of interest (ROI) analyses to measure fMRI responses during a rapid serial visual presentation (RSVP) task that elicited color-grapheme perceptual bindings for letters in synesthetes but not control participants. Both groups of subjects also performed the RSVP task with non-letter symbols that did not elicit feature bindings in either group. Anatomical ROIs were defined for each subject, and each subject also completed a separate scanning session of retinotopic mapping to define topographically-organized areas within the intraparietal sulcus (IPS). We found that synesthetes,

See page 3 for Abstract Numbering System

but not controls, exhibited greater activity for RSVP of letters compared to symbols in ventral parietal cortical regions. These ventral areas did not overlap with the more dorsally located topographic areas IPS0-5; activity in these dorsal areas did not differ between the participant groups. Furthermore, activity in ventral parietal cortex was predominantly in the right hemisphere, consistent with a right hemisphere bias for the ventral attention network. These results demonstrate that the parcellation of parietal cortex via retinotopic mapping and anatomical landmarks facilitates the identification of parietal regions involved in synesthetic binding.

61.15, *9:15 am*

Cultural differences in visual search with culturally neutral items

Jun Saiki[1](saiki@cv.jinkan.kyoto-u.ac.jp), Yoshiyuki Ueda[2], Rai Chen[1], Jonathon Kopecky[3], Ronald Rensink[4], David Meyer[5], Shinobu Kitayama[5]; [1]Graduate School of Human and Environmental Studies, Kyoto University, [2]Kokoro Research Center, Kyoto University, [3]Johns Hopkins University Applied Physics Lab, [4]Departments of Psychology and Computer Science, University of British Columbia, [5]Department of Psychology, University of Michigan

A growing number of studies in human cognition attribute the basis of cultural differences to attentional mechanisms, but few have directly investigated how it might be affected. Moreover, different kinds of conceptual distinctions such as analytic versus holistic and absolute versus relative style of processing have not been clearly distinguished. The analytic/holistic distinction is based on the structural aspect of perceptual representation, whereas the absolute/relative distinction involves evaluative aspect of perception. Furthermore, findings of cultural comparison studies using basic attentional tasks including visual search and eye movement have been equivocal, and those with visual search used culturally biased stimuli such as Chinese characters. In the current study, we provide evidence for a significant cultural difference between North American and Japanese participants in visual search with culturally neutral items, and investigated whether the difference is mediated by structural or evaluative aspect of perception. North American and Japanese participants searched for either a long line among short lines, or a short line among long lines. North American participants had a reliable search asymmetry: search for long lines among short lines was faster than vice versa. In contrast, Japanese participants had no such asymmetry —search for long lines among short lines was just as quick as short among long. If this difference reflects the structural aspect, namely analytic/holistic distinction, the search behavior should be sensitive to the item density. To test this hypothesis, the second experiment manipulated the density of stimulus items, and revealed that the difference in search asymmetry between cultures was not reliably affected by the density, indicating little difference in holistic processing between the two groups. Instead, our results suggest that—at least in visual search—differences exist in the style of stimulus evaluation, with Japanese relying more on relative than absolute stimulus values.

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61.16, *9:30 am*

Searching for riches in a changing world

Yuhong V. Jiang[1](jiang166@umn.edu), Khena M. Swallow[1], Christian G. Capistrano[1]; [1]Department of Psychology, University of Minnesota

Selective attention prioritizes a subset of sensory input for further processing. What gets prioritized is partially experience-dependent: Locations that were important in the past are more likely to be attended in the future. However, when a person moves, their location relative to previously attended regions changes. How do moving observers acquire stable attentional biases in space? We tested participants in a visual search task performed on a display laid flat on a stand. Some locations of the display were more likely than others to contain the target. Unlike most previous work, participants moved on each trial. In two experiments, high-probability locations were stable in the environment, but unstable relative to the viewer due to movement. When participants were told where the high-probability locations were, they showed an attentional bias toward those locations. However, in the absence of explicit instructions, participants failed to acquire an attentional bias toward the high-probability locations even after several hundred trials. In two other experiments, high-probability locations were variable in the environment, but stable relative to the viewer (e.g., always to the viewer's lower left). Participants failed to develop an attentional bias toward the high-probability locations, even when they were told where those locations were. Additional experiments showed that incidentally learning where a target is likely to be depends on the stability of both the viewer and the environment. However, once acquired, incidentally learned attentional biases move with the viewer. We conclude that attentional biases toward target-rich locations are directed by two mechanisms: incidental learning and endogenous (goal-driven) attention. Incidental learning codes attended locations in a viewer-centered reference frame. It is useful when viewer perspectives are limited. The use of a truly environment-centered attentional map may depend on endogenous control, which may rely on qualitatively different spatial representations than does incidental learning.

Perceptual organization: Grouping, segmentation

Wednesday, May 15, 8:15 - 9:45 am

Talk Session, Royal Ballroom 4-5

Moderator: Jonathan Peirce

61.21, *8:15 am*

Stereoscopy facilitates objects recognition in natural pictures

Baptiste Caziot[1,2](bcaziot@sunyopt.edu), Benjamin Backus[1,2]; [1]SUNY College Of Optometry, [2]SUNY Eye Institute

In brief displays, relative disparity facilitates the recognition of objects on natural backgrounds (Caziot, Valsecchi, Gegenfurtner & Backus, ECVP 2011). Is this because stereo attracts attention or because stereo specifies the object contour? To address this question we decoupled stereoscopic contours from luminance contours. Target objects had either object-defined disparity contours (ODDC) or were embedded in a rectangular local background (RDC). Performance should be better for ODDC if stereoscopic contours participate in the segmentation process. Stimuli were displayed on a rear-projection screen at 2m and fixation distance, defined by vergence demand, was 15m (approximately the distance at which background pictures were taken). Targets were 10◦ wide, centered at one of 16 locations at 12◦ eccentricity. Targets had 0, 15, 30, 60 or 120 arcmin of crossed disparity relative to fixation and the background, which portrayed a building façade. Displays lasted 33, 67, 100 or 133ms, followed by a mask. Subjects reported which of 6 possible targets was displayed. Performance increased with display duration and peaked at a disparity of 60 arcmin for both ODDC and RDC. The effect of disparity for RDC implies that disparity attracted attention, which facilitated recognition. However performance was significantly higher for ODDC than for RDC for all non-zero disparity values, but only at the longer display durations, which implies that disparity-defined object contours are useful for recognition, probably due to their contribution to segmentation. Thus, disparity facilitates image segmentation across a large range of disparities (2 deg or more) and even at short display durations (33.3 ms). Much of this facilitation results from attentional orienting, but disparity-defined contours also contribute, presumably to segmentation. Perhaps surprisingly stereoscopic contours can facilitate target recognition for diplopic targets.

61.22, *8:30 am*

Cue combination of conflicting color and luminance edges

Rebecca J. Sharman[1](lpxrs@nottingham.ac.uk), Paul V. McGraw[1], Jonathan W. Peirce[1]; [1]Nottingham Visual Neuroscience, School of Psychology, University of Nottingham, Nottingham, NG7 2RD

There is considerable evidence about how color and luminance edge cues are processed in isolation. However, it is less clear how they are combined, particularly when they conflict. Here we compare observed data with predictions from simple maximum likelihood estimation (MLE) based models. We find that chromatic cues were weighted surprisingly strongly in edge localization, given their relative reliability in isolation. Stimuli were comprised of achromatic or isoluminant bipartite fields; step-functions from black to white or red to green, presented in isolation or together. The isoluminant stimuli were designed to isolate the red-green (L-M) channel. Conflicting edges had a gap of 3 minutes of arc between the two step functions, but appeared fused. The contrast of the achromatic component was constant across conditions (0.02) and the isoluminant component was presented at three different contrasts (0.1, 0.2, 0.3). We used a method of adjustment, with unconstrained fixation and unlimited duration, to measure the perceived location of the fused edge and the variance of that judgment. Measurements from the achromatic and isoluminant stimuli were used to predict perceived location in the cue conflict condition. As expected, the reliability of the chromatic cue increased as a function of contrast and increasingly influenced perceived location of the fused edge. MLE accurately predicted the pattern of results across contrasts. However, it consistently over-estimated the relative importance of the luminance cue; this could be accounted for by a simple scale factor. Our results show that the weights generated from measurements of each

component in isolation are not sufficient to predict edge location in conflicting conditions. The chromatic component requires a higher weight than would be predicted by MLE. At contrasts for which the components cues are equally reliable for localizing the edge, the visual system gives more weight to the position predicted by the chromatic information.

Acknowledgement: EPSRC

61.23, *8:45 am*

As the nose on your face: face-superiority context effect in a simple line orientation detection task Thomas Busigny[1,2,3](thomas.busigny@uclouvain.be), Jason JS Barton[2], Linda Lanyon[2], Bruno Rossion[1]; [1]Institute of Pyschology and Institute of Neuroscience, Université Catholique de Louvain, Louvain-la-Neuve, Belgium, [2]Human Vision and Eye Movement Laboratory, Departments of Neurology, Ophthalmology and Visual Sciences, University of British Columbia, Vancouver, Canada, [3]Centre de recherche Cerveau et Cognition (CerCo), Université Paul Sabatier, CNRS-UMR 5549, Toulouse, France

Visual processing is classically modeled as a hierarchy of feedforward stages of increasing complexity (Hubel & Wiesel, 1962; Riesenhuber & Poggio, 1999). However, processing of complex stimuli may be performed initially at a coarse level in high-level visual areas, with reentrant processing to low-level areas to refine object representations (Mumford, 1992; Hochstein & Ahissar, 2002). Whether this is also true for a simple element, such as a single orientated bar, is not clear: it may be that it is processed before the detection of complex configurations, without any re-entrant processing. We tested a strong form of the re-entrant hypothesis (Gorea & Julesz, 1991), that even the detection of a line-element stimulus in a typical visual search task would be influenced by its insertion into a complex configuration. We measured the detection speed for vertical target elements embedded within arrays of 22.5° oriented noise elements, presented for a maximum of 3000ms. The vertical target element was clustered with three horizontal lines to form one of four patterns: an upright or inverted schematic face, or a symmetric or asymmetric non-face pattern. In other conditions the vertical line appeared outside the cluster. Finally, the vertical line could appear alone or with three randomly distributed horizontal lines (Fig1a). The target was detected faster when clustered with horizontal lines than when presented alone ($p<0.01$), outside the cluster ($p<0.0001$), or amongst random horizontal lines ($p<0.0001$). Most importantly, it was detected faster in the face-like pattern than in the asymmetric ($p<0.0001$), symmetric ($p<0.0001$), and inverted face-like pattern ($p<0.05$) (Fig1b). This novel face-superiority context effect points to a simultaneous activation of lower and higher visual processes. The results provide evidence for a non-hierarchical organisation in the visual system, suggesting that even simple perceptual decisions are reached through a recursive exchange of information between low and high processing levels.

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61.24, *9:00 am*

The Independence of Visual Number and Area Processing: Evidence from Psychophysics, Development, and Eye-Tracking Darko Odic[1](darko.odic@jhu.edu), Justin Halberda[1]; [1]Psychological and Brain Sciences, Johns Hopkins University

Although human and non-human animals can nonverbally estimate number, it remains unknown how the visual system extracts the number of objects from a scene. One reasonable and intuitive proposal is that number extraction begins by estimation of the total surface area that the items subsume, and then proceeds by combining this estimate with information from other dimensions, such as density (Durgin, 1995; Dakin et al., 2008). Here, we directly compare performance on number discrimination and surface area discrimination in order to test whether the encoding and representation of number and area is shared or independent. First, we tracked eye movements of observers who viewed identical displays of blobs and judged which color was greater in either number or cumulative surface area (Fig. 1a). Both number and area discrimination obeyed Weber's law, but area performance was superior to and uncorrelated with number performance (Fig. 1b,c). Critically, we found distinct eye movement patterns for the two tasks: while number trials included many saccades and short gazes, area trials involved few saccades and long gazes. This suggests that observers seek out different visual information during number discrimination than during area discrimination, even though the displays are identical. Second, we found that number and area remain distinct throughout development. A cross-sectional sample of 3-6 year olds and adults discriminated both number (with an array of dots) and area (with a blob image; Fig 2a). Once again, both number and area obeyed Weber's law, but area performance was superior to and uncorrelated with number performance (Fig. 2c). Overall, these results suggest that number and area are independent representations, and that number encoding is not learned or exclusively derived from area encoding. Instead, it would appear that the encoding of number and surface area relies on unique visual routines in both identical and non-identical visual displays.

61.25, *9:15 am*

Opposing dorsal/ventral stream dynamics during figure-ground segregation Martijn E. Wokke[1,2](martijnwokke@gmail.com), H. Steven Scholte[1], Victor A.F. Lamme[1,2]; [1]Cognitive Science Center Amsterdam, [2]Cognitive Neuroscience group Amsterdam, University of Amsterdam

The visual system has been commonly subdivided into two segregated visual processing streams: The dorsal pathway processes mainly spatial information, whereas the ventral pathway specializes in object perception. Recent findings, however, indicate that different forms of interaction (crosstalk) exist between the dorsal and the ventral stream. Here, we used transcranial magnetic stimulation (TMS) and concurrent electroencephalographic (EEG) recordings to explore these interactions between the dorsal and ventral stream during visual perception. In two separate experiments we used rTMS and single pulse TMS to disrupt processing in the dorsal (V5/HMT+) and the ventral (Lateral Occipital area) stream during a motion-defined figure discrimination task. Interestingly, we presented stimuli that made it possible to differentiate between relatively low-level (figure boundary detection) from higher-level (surface segregation) processing steps during visual perception. Results show that disruption of V5/HMT+ impaired performance related to surface segregation; this effect was mainly found when V5/HMT+ was perturbed in an early time window (100 ms) after stimulus presentation. Surprisingly, disruption of the Lateral Occipital area resulted in increased performance scores and enhanced neural correlates of surface segregation. This facilitatory effect was also mainly found in an early time window (100 ms) after stimulus presentation. These results suggest a "push-pull" interaction in which dorsal and ventral extrastriate areas are being recruited or inhibited depending on stimulus category and task demands.

Acknowledgement: ERC

61.26, *9:30 am*

Reduced Sensitivity to the Ebbinghaus Illusion is State Related in Schizophrenia Steven Silverstein[1,2](silvers1@umdnj.edu), Brian Keane[1,2,3], Keith Feigenson[1,2], Yushi Wang[2], Deepthi Mikkilineni[2], Danielle Paterno[2]; [1]UMDNJ-Robert Wood Johnson Medical School, Department of Psychiatry, [2]UMDNJ-University Behavioral HealthCare, Division of Schizophrenia Research, [3]Rutgers University, Center for Cognitive Science

Background. The Ebbinghaus illusion causes a shape to appear as larger when surrounded by small shapes and as smaller when surrounded by large shapes. Persons with schizophrenia are less susceptible to the illusion, but it is unclear when this resistance first emerges or how it varies with symptoms. Method. Chronic schizophrenia patients (n=16), first episode psychosis patients (n=11) and healthy controls (n=26) completed a psychophysical task at two different time points, corresponding to hospital admission and discharge for patients (~2 weeks apart). The task required judging the relative size of two circular targets centered on either side of the screen. Targets were either presented without context, or were surrounded with shapes that made the size judgment harder or easier (misleading and facilitating contexts, respectively). Results. Performance without context was consistently the same across groups, indicating that all subjects were engaging in the task appropriately. At hospital admission, the accuracy difference between the facilitating and misleading conditions was larger in controls than in first episode patients, and larger in first episode than chronic patients. Notably, the chronic group was significantly more accurate than the other groups with misleading context, and less accurate with facilitating context, indicating reduced context sensitivity. At discharge, all groups performed similarly. Finally, a reduction in psychotic and disorganized symptoms across time points was correlated with a reduction in accuracy in the misleading condition, and an increase in accuracy in the facilitating condition for the chronic group. Conclusions. Resistance to the Ebbinghaus illusion arises by the first episode of psychosis, depends on current symptom level, and becomes more pronounced as more psychotic episodes are experienced. This suggests that visual context processing is a state-marker in schizophrenia, and that psychosis and disorganization can elucidate the mechanisms that subserve normal visual context processing.

Acknowledgement: NIMH R01MH093439

Spatial vision: Neural mechanisms and models

Wednesday, May 15, 10:45 - 12:45 pm

Talk Session, Royal Ballroom 1-3

Moderator: Michael Pratte

62.11, *10:45 am*

Investigating Inhibitory Circuits of Visual Cortex David Lyon[1](dclyon@uci.edu), Yongjun Liu[1], Moritz Negwer[1], Hanjuan Shao[1], Markus Ehrengruber[1]; [1]Anatomy and Neurobiology, School of Medicine, UC Irvine

In primary visual cortex (V1), inhibition is essential for several basic functional characteristics of individual neurons, including preferences for stimulus contrast, size, and orientation, that provide the building blocks for object perception. While inhibitory neurons serve to control excitation it is not known whether inhibitory and excitatory cell-types are mediated through the same set of cortical circuits, nor whether the functional selectivity of these circuits differ. This is largely due to technical limitations, since inhibitory and excitatory neurons are intermingled and the study of one population over the other is difficult to achieve. To overcome this, we developed a technique for labeling pre-synaptic inputs to either inhibitory or excitatory neurons that uses viral vectors with cell-type specific promoters and a modified rabies virus. The method labels thousands of connected cells with fluorescent proteins that distinguish them from the inhibitory or excitatory starter cells. Initial experiments reveal that the dominant source of input to both inhibitory and excitatory V1 neurons is local in origin. In addition, we find that long-range intrinsic inputs to inhibitory neurons are as sharply tuned to the preferred orientation as has been shown using non-specific tracers. Third, feedback from higher visual areas is also present, but the percentage of feedback to excitatory cells is much greater (~20%) than found for inhibitory cells (<10%). Together these results suggest that, compared to intrinsic circuits feedback has less direct control over inhibition than excitation. This difference could have important implications for such processes as contextual modulation of V1 cells which is thought to be mediated in different ways through intrinsic and feedback pathways. Because the rabies virus used in this technique can also be engineered to simultaneously deliver genes for optogenetics, future applications can involve the direct manipulation of each circuit to determine their functional impact on target neurons.

Acknowledgement: NINDS NS072948

62.12, *11:00 am*

Identifying the relationship between fMRI BOLD response and neuronal activity with an achiasmatic human subject Bosco S. Tjan[1,2](btjan@usc.edu), Pinglei Bao[2], Chris Purington[1]; [1]Department of Psychology, University of Southern California, [2]Neuroscience Graduate Program, University of Southern California

Inferring neuronal activity from BOLD response is hard. Their relationship is masked by the nonlinearity between stimulus and neuronal activity. Furthermore, neuronal activity is multi-faceted and difficult to quantify even with direct, invasive simultaneous recording methods. Now consider a hypothetical system with two identical groups of non-interacting neurons that are co-localized in the same capillary bed and control the same local vascular network. Further suppose that we can manipulate each group independently with stimuli. This system would be ideal for mapping the relationship between neuronal activity and BOLD response, circumventing the unknown composition of neuronal activity and the unknown relationship between stimulus and neuronal activity – presenting identical stimuli to both groups of neurons will, by definition, double neuronal activity in the local region. We found such a system in low-level visual areas of humans born without optic chiasm. For achiasmatic subjects, we and others have found that each fMRI voxel in V1-V3 has two population receptive fields (pRFs) symmetrically located across the vertical meridian (Hoffmann et al., 2012 Neuron, Purington et al., 2012 VSS). We have further demonstrated that the co-localized neurons of these pRFs do not interact (Bao et al., 2012 VSS). By presenting stimuli to one or both of the pRFs in these pairs, we found that resulting BOLD responses to cross-pRF spatial and temporal summations manifest the same dynamic nonlinearity inherent in biophysical models of hemodynamic response, such as the Balloon model (Buxton et al., 1998 MRM), devoid of any neuronal nonlinearity. We have thus empirically demonstrated that the Balloon model and models with similar nonlinearity accurately describe the relationship between BOLD response and neuronal activity. The visual cortex of an achiasmatic subject is a powerful tool for untangling hemodynamic and neuronal nonlinearity in phenomena such as fMRI adaptation, surround suppression, and spatial summation.

Acknowledgement: US National Institutes of Health grant R01-EY017707 US National Science Foundation grant BCS-1255994

62.13, *11:15 am*

Decomposition of stimulus representations and decision-bias signatures in population activity of human primary visual cortex 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]Psychology Department, Vanderbilt Vision Research Center, Vanderbilt University

The precise role of primary sensory cortex in forming perceptual choices remains elusive. In some studies trial-to-trial fluctuations in responsiveness within primary visual cortex (V1) are tightly correlated with observers' perceptual responses to repeated presentations of otherwise identical stimuli (Ress and Heeger, 2003; Palmer et al., 2007); in other studies no such correlation is observed (Grunewald et al., 2002; Nienborg and Cumming, 2006). At the same time, non-sensory factors such as task structure (Jack et al., 2006; Cardoso et al., 2012) or decision bias (Nienborg and Cumming, 2007) do appear to impact neural activity within early visual cortex. To elucidate V1's contributions to perceptual decisions, we measured fMRI responses from V1 while 19 human observers performed a difficult visual discrimination task (performance: 73.7% ± 5.7% correct) and assessed simultaneously whether and how population activity in V1 represents stimuli presented and signifies choices and decision biases exhibited by observers. Over trials one of three briefly presented (0.3s), different-sized rings (2.78°, 2.84°, and 2.90°, randomly presented) was categorized by observers as 'small' or 'large'. A large fraction of fMRI responses in V1 fluctuated in unison, leading us to decompose raw fMRI response profiles as a function of eccentricity (RRs) into 'untuned responses' (URs, average of RRs across eccentricities) and 'tuned responses' (TRs = RRs-URs). TRs readily resolved threshold-level differences among stimuli with high fidelity (stimulus probability: 0.57 ± 0.06; mean ± SD) but failed to predict perceptual choices made by observers. URs, on the other hand, correlated significantly with the inter-observer variability in decision bias (Pearson's r=0.52, p=0.02). These results suggest that population responses in V1 encode external stimuli with high fidelity but their trial-to-trial variability is unlikely to signify trial-to-trial variability in actual choice selection. The relationship between untuned V1 activity and decision bias could presage an expanded conceptualization of global fluctuations in early visual cortex, perhaps reflecting sensory gating via neuromodulatory feedback mechanisms.

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62.14, *11:30 am*

Assessing Tilt Illusions in Human Visual Cortex Using fMRI and Multivariate Pattern Analysis Michael Pratte[1](prattems@gmail.com), Frank Tong[1]; [1]Psychology Department and Vanderbilt Vision Research Center, Vanderbilt University

When a central target grating is flanked by a similarly oriented surround, the orientation of the target is repulsed away from that of the surround; when the target and surround have very different orientations (>50 degrees) the target orientation is attracted toward the surround. Although the psychophysical properties of these tilt repulsion and tilt attraction illusions are well known, there has been surprisingly little investigation of their neural basis. Here, we examined whether orientation-selective activity patterns in early visual areas might be systematically biased for a target grating when presented in the context of a surrounding grating. Participants were shown randomly oriented target gratings either in isolation or with a vertically oriented surround during fMRI scanning. We developed novel decoding analyses that provide accurate estimates of the orientation corresponding to a voxel activity pattern. These decoding techniques were used to determine how the presence of the surround orientation influenced orientation-selective responses to the target grating. In extrastriate visual areas V2 and V3, we found robust tilt repulsion and attraction effects in the decoded orientations. These biases in cortical orientation responses were consistent with typical psychophysical effects, with tilt repulsion peaking at an orientation difference of about 20 degrees between target and surround, and tilt attraction peaking at a difference around 60 degrees. In V1, however, repulsion effects were smaller and attraction effects were absent, a finding that is potentially consistent with models proposing that tilt attraction effects arise from later stages of visual processing. Our findings provide novel evidence to inform our current understanding of the neural bases of human orientation perception, by showing that contextual effects induced by a surrounding grating systematically bias orientation-selective responses in early visual areas.

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62.15, *11:45 am*

Combining Perceptual Estimates Using Recursive Conditional Means (RCM) Wilson Geisler[1](geisler@psy.utexas.edu), Jeffrey Perry[1]; [1]Center for Perceptual Systems, University of Texas at Austin

Many tasks performed by real and artificial visual systems involve combining multiple noisy estimates of a given variable (e.g., depth) to obtain a more accurate estimate of the variable. In the classic approach, estimates are obtained independently (e.g., in parallel) and then combined linearly, where the weight on each estimate is its relative reliability. We describe a more powerful and computationally efficient approach, where estimates are obtained and combined recursively. This approach is demonstrated for estimates based on natural image statistics in the specific task of denoising images corrupted with multiplicative (Poisson-like) noise, but the approach is applicable to many visual processing tasks. First consider the classic approach for the case where each estimate is a Bayesian optimal estimate given a particular set of observed variables (a "context"). If the goal (cost function) is to minimize squared estimation error, then each optimal estimate is simply the conditional mean of the unknown variable given the context, and the reliability of each estimate is the inverse of the conditional variance given the context. As mentioned above these estimates are combined linearly to get the final estimate. Now consider the RCM approach. In this case, each estimate is also a Bayesian optimal estimate based on a context. However, the estimates obtained from the first context serve as part of the second context; the estimates from the second context serve as part of the third context; and so on. We show that the RCM approach performs better than the classic approach, does not require knowing conditional variances, and yields denoising performance that exceeds the state-of-the-art algorithms in the image processing literature. Importantly, the RCM approach is simple and could be implemented hierarchically with plausible neural circuits. Thus, it represents a viable new alternative for how sensory estimates are combined in neural systems.

Acknowledgement: NIH EY11747

62.16, *12:00 pm*

What Determines Contrast Sensitivity: An External Noise Study Across Spatial Frequencies? CHANG-BING HUANG[1](huangcb@psych.ac.cn), Ge Chen[1], Fang Hou[2], Fangfang Yan[1], Pan Zhang[1], Zhong-Lin Lu[2]; [1]Key Laboratory of Behavioral Science, Institute of Psychology, Chinese Academy of Sciences 16, Lincui Rd, Chaoyang Dist., Beijing, 100101, China., [2]Laboratory of Brain Processes, Department of Psychology, Ohio State University

Although it has greatly improved our understanding of a variety of sensory inefficiencies, pathological degradation, and system state changes (Ahumada & Lovell, 1971; Lu & Dosher, 2008; Ahumada, 1987; Geisler, 1989; Legge, Kersten, & Burgess, 1987; Lu & Dosher, 1999, 2001; Pelli, 1981, 1990; Huang, Tao, Zhou, & Lu. 2007), application of the external noise paradigm and observer models is usually implemented in a single spatial frequency condition. It is not clear how the various efficiencies vary across spatial frequencies and how they are related to the contrast sensitivity function (CSF). In the current study, we applied the external noise method and perceptual template model to stimulus conditions over a wide range of spatial frequencies. We evaluated how the various sources of observer inefficiency change with spatial frequency and determined the limiting factors underlying the contrast sensitivity function. The method of constant stimuli was used to measure contrast psychometric functions for a 2-AFC grating detection task at five spatial frequencies (0.5, 1, 2, 4 and 8 cpd) and eight external noise levels in four subjects. Each psychometric function was sampled at five contrast levels, based on pilot tests for each subject. There were a total of 200 combinations of spatial frequency, external noise and contrast levels (5*8*5), and 18,000 trials (200 conditions*90 trails/condition). We found that only internal additive noise (by more than 1000 times) and gain of the perceptual template (less than 2 times) changed significantly with spatial frequency, while transducer non-linearity and coefficient for multiplicative noise were constant. The 12-parameter model provided a very good account of all the data in the 200 conditions (87.5%, 86.0%, 90.0% and 96.4% for the four subjects, respectively). Our results contradict models that filter their inputs with CSF, and may shed new light on contrast sensitivity deficits in clinical populations.

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62.17, *12:15 pm*

Extracting Modulation Transfer Function of the Visual System from Contrast Sensitivity Function in External Noise Zhong-Lin Lu[1](lu.535@osu.edu), Fang Hou[1], Chang-Bing Huang[2]; [1]Deparment of Psychology, The Ohio State University, [2]Institute of Psychology, Chinese Academy of Sciences

The contrast sensitivity function (CSF) provides a comprehensive measure of spatial vision. Many have treated it as the spatial modulation transfer function (MTF), reflecting the gain of the visual system to various spatial frequencies, and used it to define the profile of the first stage filter in models of spatial vision (Ginsburg 1986; Chung, Legge and Tjan 2002; Watson and Ahumada 2005). Equating the MTF of the visual system to the CSF might however be problematic because contrast thresholds are jointly determined by the gain, internal noises and other nonlinearities in the visual system (Lu and Dosher 1999; Pelli and Farell 1999). Here, we applied the external noise paradigm and the perceptual template model (PTM) to separate contributions of the various factors to the CSF and extract the MTF of the visual system. Psychometric functions of five observers in a 10-AFC letter identification task were measured in five spatial frequencies and two external noise conditions (0 and 20%). The Sloan letter stimuli were filtered by a log-cosine filter centered at 3 cycles per letter with a 1-octave bandwidth, and scaled into different retinal spatial frequencies (0.5, 1, 2, 4 and 8 cpd). In the high external noise condition, the noise images were scaled with the letter size to maintain 18 noise elements per letter. We found that two factors contributed to the shape of the CSF: (1) additive noise accounted for 92±3 % of the variance, (2) a mostly flat but slightly dropped (about 11.8%) MTF at the highest spatial frequency accounted for an additional 4-5% of the variance. These results suggest that the MTF of the visual system, i.e., its gain to different spatial frequencies, is quite different from the CSF. The methods and results developed in this study may have broad implications for models of spatial vision.

Acknowledgement: NEI grant EY021553.

62.18, *12:30 pm*

Modeling letter identification: contrast thresholds as a function of size Andrew Watson[1](andrew.b.watson@nasa.gov), Albert Ahumada[1]; [1]NASA Ames Research Center

Letter identification is a canonical topic in the study of human visual pattern identification. It serves as a natural example of identification of a finite set of well-learned simple spatial patterns, and also underlies most tests of visual acuity. As part of our effort to develop a model of image identification (Watson & Ahumada, 2008, doi:10.1167/8.4.17; Watson & Ahumada, 2012, doi:10.1167/12.10.19) we have reviewed the published data for contrast thresholds for letter identification as a function of size. Eight studies, examining letter sizes from 0.04 to 60 degrees and employing a variety of stimulus materials and conditions, agree that sensitivity increases rapidly with size from the acuity limit, but then saturates, and may decline slightly, for letter sizes above about 1 degree. None of these studies has offered a comprehensive account of this pattern of results. We have explored the performance of a template model limited by optics, eccentricity-dependent retinal filtering and sampling, neural noise, and an efficiency that varies with pattern size. Optical limits were derived as the mean MTF from wavefront aberrations of 200 normal observers (Thibos et al., 2002, doi:10.1364/JOSAA.19.002329). Retinal limits were derived from a formula for human midget retinal ganglion cell densities developed by Drasdo et al. (2007, doi:10.1016/j.visres.2007.01.007) and extended by us to two dimensions. Anisoplanatic spatial filtering used a generalization of the method of Perry and Geisler (2002, doi:10.1117/12.469554). Efficiency values were derived from Pelli et al. (2006, doi:10.1016/j.visres.2006.04.023). Noise value was derived from template model fits to ModelFest Gabor contrast thresholds (Watson & Ahumada, 2005, doi:10.1167/5.9.6). With no free parameters, the model provides a good description of the ensemble data. We find that all model components are required to account for the pattern of results.

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Face perception: Expressions, social

Wednesday, May 15, 10:45 - 12:45 pm

Talk Session, Royal Ballroom 4-5

Moderator: Rachael Jack

62.21, *10:45 am*

Beyond Facial Morphology: Social Impressions from Dynamic Face Gestures

Daniel Gill[1](daniel.gill@glasgow.ac.uk), Oliver Garrod[1], Rachael Jack[1], Philippe Schyns[1]; [1]Institute of Neuroscience and Psychology, University of Glasgow

Social trait inference from faces exerts a huge impact on social outcomes ranging from mate choice to voting preferences (Todorov et al. 2005; Rhodes, G., 2006). Although previous studies have identified from static faces the morphological face features which influence social judgements (Dotsch & Todorov, 2012), the question is whether the dynamics of facial muscles can flexibly and transiently produce specific expressions that signal important social traits for social interactions. We addressed this question by: (i) quantifying the influence of dynamic facial expressions on judgments of social traits; (ii) teasing apart the contribution of facial morphology and facial expressions to social trait judgments; and (iii) measuring the similarities of facial expressions between social traits and emotions. We used a computer graphics platform that parametrically controls the dynamics of any facial muscle group (coded as 41 different Action Units, Ekman, 1978), each animated with 6 temporal parameters: peak amplitude, peak latency, onset latency, offset latency, acceleration, deceleration (Yu et al. 2012). Twelve participants judged the trustworthiness, dominance, attractiveness (and perceived intensity) of a series of facial animations of randomly chosen Action Units and their dynamic parameters. Reverse correlation estimated the expressions as sets of facial movements associated with the perception of each social trait and their intensity. Results were highly consistent between participants, with attractiveness and trustworthiness positively correlated with each other and negatively correlated with dominance. In addition, a comparison of these facial expressions with those similarly derived for facial emotions (Jack et al. 2012) showed that social trait expressions are not simple one-to-one overgeneralisations of emotional expressions, but a distinct set of signals composed of movements from different emotion categories. To conclude, we show that the face can flexibly and transiently produce facial movements that modulate social signals of attractiveness, trustworthiness and dominance that are paramount for social interactions.

Acknowledgement: Economic and Social Research Council grant ES/K00607X/1

62.22, *11:00 am*

Social Perception Deficits in Children with Autism Spectrum Disorder

Kami Koldewyn[1](kamik@mit.edu), Sarah Weigelt[1], Nancy Kanwisher[1]; [1]Department of Brain and Cognitive Sciences, McGovern Institute for Brain Research, Massachusetts Institute of Technology

Both children and adults with autism spectrum disorders (ASD) are widely claimed to perform worse than their typically developing (TD) peers in identifying people from their facial appearance. Despite a substantial literature on face perception in ASD, two important questions remain. First, is the recognition deficit in ASD specific to faces or is it also evident in other visual categories (i.e., is it domain specific)? Second, does the recognition deficit in ASD reflect a greater impairment in face memory than in face perception (i.e. is it process specific)? Here, we address these two questions by testing 47 children with ASD, aged 5 to 12, and an age and IQ-matched group of TD children on one task testing memory and one testing perceptual discrimination on the same stimuli– across four stimulus categories: faces, human bodies, cars and scenes. Children with ASD performed worse than their matched TD comparison group on face and body memory, but not car or scene memory. However, only face memory performance was correlated with autism severity, strongly suggesting that it may be an important part of the ASD phenotype. Perceptual discrimination deficits were not significant for faces, suggesting that the face recognition deficit reflects a specific problem with face memory, not face perception. While no perception deficits were seen in non-social stimuli (cars, scenes), children with ASD did show body perception deficits, suggesting children with ASD may have more general deficits in social perception. Our results indicate that the face recognition deficit in ASD is domain specific (to social stimuli), and also process specific (to memory but not perception).

Acknowledgement: Simons Foundation, Ellison Medical Foundation

62.23, *11:15 am*

Individual differences in the ability to recognize facial expressions are associated with the strength of adaptive expression coding but not the strength of holistic expression coding.

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There are large, reliable individual differences in the recognition of facial expressions but the source of this variation is not known. We investigated whether the ability to recognize facial expressions is associated with individual differences in the strength of two key face perception mechanisms – holistic coding of facial expression and adaptive coding of facial expression. Expression recognition ability was measured by three tasks that involved the matching and labeling of static and dynamic facial expressions. Holistic coding of expression was measured with three composite effect tasks: two in which participants labeled the expression of aligned and misaligned face composites; and one in which they judged whether two sequentially presented face composites were the same or different. Adaptive face coding was measured with an expression aftereffects task in which participants adapted to anti-expressions of fear, anger, sadness and happiness, and then judged the expression of briefly presented faces. A size change was included to minimize low-level adaptation. Despite good internal reliability and substantial range across individuals, we found no association between the ability to recognize facial expression and the strength of holistic coding of expression. This suggests that individual variation in facial expression recognition, unlike facial identity recognition, does not rely upon holistic processing. In contrast, the ability to recognize facial expression was strongly associated with the strength of facial expression aftereffects. This suggests that the ability to update face norms may play an important role in facial expression recognition ability. This is similar to facial identity recognition, where recent evidence finds individual variation in identity recognition is correlated with the strength of face identity aftereffects. Overall, results suggest that expression processing has both similarities to, and differences from, face identity recognition.

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62.24, *11:30 am*

Asian and Caucasian observers' initial eye movements during face identification are similar and optimal

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It has been proposed that East Asian and Western Caucasian observers employ different eye-movement strategies during face identification, with Asians preferring to fixate towards the face centre (Blais et al., 2008, PLOS ONE). Here, we evaluated whether Asian and Caucasian observers differed in the location of task-critical first eye movements during a fast face-identification task. Using a foveated ideal observer (Peterson & Eckstein, 2012, PNAS), we assessed whether the pattern of behaviour can be explained by an interaction between the race-specific distribution of discriminatory information in faces and the varying spatial resolution across the visual field. Methods: Asian and Caucasian observers (16 each) participated in two experiments: one, identifying Asian faces among other Asian faces; another, identifying Caucasian faces among other Caucasian faces. In each condition, observers viewed and identified briefly presented faces (350 ms; 7.7° between eyes and mouth) using a 10-alternative forced-choice match-to-sample paradigm, while their eye movements were monitored. Results: No significant differences ($p = .69$) were found between Asian and Caucasian observers' first saccades, with an average landing position 1.1° below the eyes regardless of the face race presented. A subsequent experiment that forced observers to fixate at different regions of the face confirmed the functional importance of fixating just below the eyes for either race of observers and stimuli: Fixations further from the preferred points led to decreased accuracy. A foveated ideal observer that integrates information in face images optimally but is constrained by the decrease in visual sensitivity as a function of retinal eccentricity predicted the same optimal regions of fixation for Asian and Caucasian faces. Conclusion: People of both races

employ similar task-critical first eye movements. These first eye-movement strategies are optimal based on the distribution of discriminatory information within same-race faces and the foveated nature of visual processing.

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62.25, *11:45 am*

Fast and slow object priming of fearful and happy facial expressions

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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 objects affect the speed at which a facial expression is recognized. In this experiment, a person presenting a neutral expression was shown with either a positive emotional object (money, birthday cake), a negative emotional object (spider, gun) or a neutral object (stapler, spoon). The objects appeared at one of four stimulus onset asynchronies (SOA) (0 ms, 100 ms, 300 ms, 500 ms). Following the SOA interval, the neutral expression of the person changed to a happy or a fearful expression. The participant's task was to categorize the expression as "happy" or "fear" as quickly and accurately as possible. Overall, reaction time was faster when the expression was accompanied by congruent objects than when shown with incongruent or neutral objects. Congruency also interacted with emotion and SOA. At the shortest SOA (0 ms), participants were faster to categorize the "fear" expression when preceded by the congruent negative objects than when preceded by incongruent positive objects. At the longest SOA (500 ms), participants were faster to categorize the "happy" expression when preceded by congruent positive objects than when preceded by neutral or incongruent negative objects. The obtained results demonstrate that single objects with strong emotional associations can prime the recognition of facial expressions. Object priming for happy and fearful expressions seem to follow separate timing trajectories. Whereas fear is a "fast" emotion that is rapidly primed by a negative object, happy is a "slow" emotion that is gradually primed by a positive object.

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62.26, *12:00 pm*

Behavioral The Behavioral Effects of Adaptation to Facial Expressions are Explained by Changes in the Decision-Making Process

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Perceptual aftereffects arising from adaptation have been widely used as a tool for exploring the neural representation of visual stimuli as simple as spots of color or as complex as faces. In most adaptation studies subjects make decisions about the appearance of a test stimulus presented alone or after viewing an adapting stimulus. Changes in decisions are commonly attributed to changes in sensory representation. Potential changes in the decision-making strategy, however, are rarely studied. Here, we utilize recent advances in our understanding of the decision-making process to disentangle representational and decisional effects of adaptation. A pure representational effect modifies the sensory evidence furnished by the test stimulus and is expected to cause equivalent shifts in the subject's psychometric and chronometric functions. On the other hand, a change in the starting point or termination criterion of the evidence accumulation process can introduce asymmetries in the chronometric function. We tested these two hypotheses in a facial emotion adaptation task in which the subject reported whether a test face was happy or sad. The test stimuli were drawn from a spectrum of happy to sad faces of an individual and evaluated in three conditions: no adaptation, adaptation to a happy face, and adaptation to a sad face. As expected, adaptation shifted the perceived neutral face toward the adaptor. Surprisingly, reaction times for the two response categories (happy, sad) changed asymmetrically: for a fixed test stimulus responses opposite to the adapting category (adapt happy respond sad) were faster. A second experiment shows that our observation is invariant to adaptor size or location. These behavioral patterns are more compatible with a change in the decision-making process than a representational change. It is possible that the underlying neural mechanism for high-level face adaptation differs from low level adaptation, which may be best explained by representational changes.

62.27, *12:15 pm*

Contrast negation reveals a dissociation in the neural representations underlying the perception of facial identity and expression

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Visual information from a face can be broadly divided into either surface-based texture patterns or shape-based cues derived from feature edges. Contrast negation disrupts the surface texture of faces, but leaves shape-based information largely intact. Our aim was to use contrast negation to determine the relative contribution of these different types of facial information to the perception and neural representation of identity and expression. In Experiment 1, we asked how judgements of expression and identity are affected by contrast negation. Participants had to judge either the identity or the expression of two sequentially presented gray-scale faces in 4 conditions: (1) same-expression, same-identity; (2) same-expression, different-identity; (3) different-expression, same-identity; (4) different-expression, different-identity. The faces in each condition were either both positive-contrast, both negative-contrast, or mixed positive- and negative-contrast. Contrast negation had a significant effect on judgements of facial identity, but only a marginal affect on judgements of expression. This shows that judgements of facial identity are more sensitive to surface texture information. Experiment 2 used fMRI to ask whether the neural representations in different face-selective regions are sensitive to surface-based texture patterns. Twenty-five participants viewed blocks of faces that had either the same identity and expression or different identities and expressions. The faces in each block were either (1) all positive contrast, (2) all negative contrast or (3) alternated between positive and negative contrast. We found significant adaptation (different > same) to positive-contrast, but not to negative-contrast or positive/negative-contrast faces in the FFA. However, significant adaptation to all face conditions was evident in the pSTS. These results suggest that neuronal representation in the FFA is sensitive to surface-based cues that are important for the perception of facial identity. In contrast, the neural representation in the pSTS is dependent upon shape-based cues that are important for the perception of facial expression.

62.28, *12:30 pm*

Dynamic signaling of facial expressions transmit social information in a hierarchical manner over time

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Designed by both biological (Susskind et al., 2008; Andrew, 1963) and social evolutionary pressures (Darwin, 1999/1872), facial expressions transmit specific sequences of information across time to achieve an optimal system of social signaling and decoding (Darwin, 1999/1872; Schyns et al., 2009). Here, we show for the first time that this dynamic signaling transmits social information over time in a hierarchical manner that fits evolutionary pressures. We proceeded in two steps. First, we used 4-dimensional (3-dimensional face over time) reverse correlation to reconstruct the dynamic mental models of the 6 basic facial expressions of emotion, for 60 Western Caucasian observers individually (Yu et al., 2012; Jack et al., 2012. See Figure S1, Panel A). Second, from the distribution of mental models, we constructed a 6-choice Bayesian classifier (see Bayesian Classifiers in Supplementary Material) that accrues Action Unit (AUs; Ekman et al., 1972) signals over time, as a function of their availability. Analyses revealed that early facial signalling leads to systematic confusions ($p<.01$. See Figure S1, Panel B, pink boxes) between fear and surprise (and also disgust and anger), due to specific shared AUs (eye lid raiser and nose wrinkler, respectively. See Figure S1, Panel C, pink boxes). Accurate discrimination of each one of the six basic emotions is delayed by the later availability of diagnostic AUs (e.g., eye brow raiser and upper lip raiser, respectively. See Figure S1, Panel C, green boxes). We conclude that the face transmits social signals in a hierarchical manner that fits evolutionary pressures: Initially, the eye lid raiser and the nose wrinkler signal two types of danger (Susskind et al., 2008; Lee et al., in press; Chapman et al., 2009), which, with the addition of diagnostic AUs, are distinguished further into the six basic emotions (e.g., surprise) and their subtypes (e.g., positive vs. negative surprise).

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Wednesday Morning Posters

Attention: Tracking, shifting

Wednesday, May 15, 8:30 am - 12:30 pm

Poster Session, Royal Ballroom 6-8

63.301 Role of attention, eye-movements, and landmarks in tracking an occluded object.

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We extend our 2012 VSS study of tracking a single object that moves behind an occluding surface. Observers tapped the screen when cued by a sound to indicate where the moving object was at the time of the sound. We measured gaze and touch localization when the object was either occluded or visible, with or without landmarks. We found gaze and touch undershoot target position in occlusion trials especially later in tracking (>1.9 s), and that localization was not affected by landmarks. Here we test whether the lag-bias reflects coding of object position by the eye-movement system by comparing tracking with attention (gaze constrained) vs. free eye-movements, and whether landmarks help track hidden objects when gaze is constrained. Method: Seventy-five participants tracked a (1°) square that moved (4°/s) across marked, or unmarked (5-s) trials. Marks were a row of 10 asterisks along the object's path. A sound probe (SP) occurred randomly between 1.3 and 3.8s after the square started moving. Location response was indicated by subjects tapping their forefinger to indicate object-position (hidden on 1/2 the trials). Thirty participants tracked the square with their gaze fixated on the center of the screen, and a 2nd group of 45 participants were free to track the object with their eyes. Results. Best localization occurred when the tracked object is visible, and early in the tracking sequence (0.3° overshoot). In occlusion trials, tap lags behind the object (4.5°) and lag increases with tracking distance. Landmarks have a different effect depending on fixation and SP delay: When centrally fixated, landmarks help localize the hidden object (lag is reduced 0.8°), but hinders localization of the hidden object when gaze moves freely (reaching 8.0° at 3.8s). We discuss how eye-movements help localize hidden objects, but when gaze is constrained, attention uses landmarks to help guide tracking.

63.302 Capture and tracking: Where does attention go?

Justin M. Ericson[1](jerics1@lsu.edu), Rebecca R. Goldstein[1], Melissa R. Beck[1]; [1]Department of Psychology, Louisiana State University

Unexpected changes in object trajectory can attract attention (Howard & Holcombe, 2010) and, increasing the number of changes in target trajectories during a multiple object-tracking (MOT) task negatively influences tracking accuracy (Ericson & Beck, OPAM 2011). Therefore, attention may be preferentially allocated to items that have recently changed trajectory and away from other items that could subsequently also change trajectory. It follows that MOT performance is poorer with more changes because attention is less likely to be available for allocation for every change in trajectory. We tested this possibility by incorporating a probe detection task immediately after a target abruptly changed direction. Using a rotational tracking design, four target-distractor pairs rotated independently of each other and each pair abruptly changed trajectory during the motion sequence either one or six times. During each trial, one probe appeared on a target. The probe always appeared immediately after a target changed trajectory. Probes were presented for 250 ms and appeared on the target that had just changed trajectory or one of the other targets. Participants were instructed to track the four targets and press a button each time a probe appeared. Replicating our changes in trajectory effect; when the probe was accurately detected, MOT performance was higher in the one-change condition than the six-change condition. Overall probe detection was higher for trials with six trajectory changes. Importantly, on accurate probe detection trials, reaction times were faster for the one-change trials compared to the six-change trials when the probe was on the same item, suggesting that attention was not allocated to the change item at the time the probe appeared in the six-change condition. These results suggest that although attention may be distributed across all target objects in a MOT task, attention may also be allocated preferentially to one item depending on task demands.

63.303 Load-dependent but short-range spatial interference in multiple object tracking

Alex Holcombe[1](alex.holcombe@sydney.edu.au), Piers Howe[2], Wei-Ying Chen[1]; [1]School of Psychology, University of Sydney, [2]School of Psychological Sciences, University of Melbourne

Tracking performance declines when more targets must be tracked. Why? We previously documented one reason: temporal resolution is poorer when more targets are tracked (Holcombe & Chen, VSS 2012). For tracking one target, the temporal frequency threshold was 7 Hz - if distractors occupied former target locations more frequently than every 143 ms, tracking performance was poor. Tracking two targets yielded 4 Hz thresholds. Spatial resolution may also be poorer when more targets are tracked (Franconeri et al., 2008). We were interested in the range of such load-dependent spatial interference. Objects in our display were paired, with each pair sharing a circular trajectory centred on 8.5 deg. eccentricity, forming a "binary star". Two such binary stars were presented simultaneously with their trajectories separated by 1, 2, 3, 5, 7, or 9 deg. When there was only one target, speed thresholds for tracking were approximately 2.0 revolutions per second for all separations. When there were two targets, one in each binary star, thresholds were approximately 1.8 rps for all separations greater than 1 deg. At the separation of 1 deg however, the speed limit for tracking two targets fell to 1.6 rps, implicating short-range spatial interference that is greater when tracking two targets. Beyond 1-2 deg, the constant 1.8 rps limit suggests there is no distance-dependent spatial interference. In typical MOT displays, objects are free to approach and even touch each other. Our results suggest that in close encounters of 1 deg or less (where eccentricity is 8.5 deg), spatial interference causes tracking errors. At separations larger than that distance, spatial interference does not appear to be significant. More work is needed to determine the circumstances where spatial resolution rather than temporal resolution limits tracking, but the evidence here suggests that spatial resolution is confined to relatively short distances.

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63.304 Attention restores awareness of changing colors in moving objects

Scott McLean[1](smclean@psych.udel.edu), James E. Hoffman[1]; [1]University of Delaware

Suchow and Alvarez (2011) discovered an interesting illusion in which motion appears to "silence awareness" for otherwise salient color changes in a set of objects. They showed that a continuous change in the hue of stationary objects is, perhaps not surprisingly, obvious to the observer. However, when the circles are set in motion, awareness of the changing colors is completely suppressed. We investigated whether this form of change blindness, like other change blindness phenomena, can be eliminated when visual attention is directed to the changing object. Participants had to track a set of moving target objects in a large set of moving distractors with random static colors. On 70% of the trials, one of the targets began changing color at a random delay after the start of the trial. On the remaining trials, none of the targets changed color and the observer was tested on which objects were targets. Observers were instructed to press a key as soon as they detected a color change and refrain from making false alarms. Color change detection was fast and accurate only when the number of tracked objects was within the observer's tracking capacity. These results show that motion silencing of awareness can be overcome when attention is allocated to the changing object even when it is moving and fixation is maintained on the center of the display. Similar to other cases of change blindness, visual attention plays an important role in detecting change that is masked by motion.

Acknowledgement: Funded by NSF grant BCS-1059560 to James E. Hoffman

63.305 Visual Attention is Required for Multiple Object Tracking

Annie Tran[1](atran@udel.edu), James Hoffman[1]; [1]University of Delaware

Pylyshyn and Storm (1988) proposed that observers track multiple objects by assigning pointers to the targets. These pointers are thought to be part of a preattentive mechanism that is independent of attention, and allow observers to reference the location of the targets without providing any information about its properties or identity. Access to object properties is provided by allocating attention to that object. An alternative explanation for multiple object tracking is the "spotlight of attention" model. This model holds that attention is a flexible resource that can be allocated to each target, a process that is necessary for object tracking (Alvarez & Franconeri, 2007). In our experiment, we attempted to determine whether visual attention is required for tracking. Observers were required to track multiple moving

objects while trying to discriminate a letter target appearing at a random time on one of the objects. The letter was presented by removing segments of a figure eight object, thus reducing onset cues. In different blocks of trials, we systematically varied the probability of the letter appearing in tracked objects vs. distractors. If attention is not required for tracking, then attention should be preferentially allocated to objects that are likely to contain the search target. However, if attention is necessary for tracking, then good tracking performance should be accompanied by superior detection of letters appearing on tracked objects compared to distractors and this effect should be independent of the probability manipulation. Our results indicated that the probability manipulation had no effect on observers' letter discrimination speed, $F(2, 18) = 1.63$, $p = .23$. Letters on tracked objects were consistently identified faster relative to distractors, $F(1, 9) = 34.72$, $p<.001$ and this effect did not interact with probability, $F(2, 18) = 2.23$, $p = .16$. Allocation of attention to tracked objects appears to be obligatory.

Acknowledgement: Research supported by NSF grant BCS-1059560 to JEH.

63.306 The profile of multifocal attention: surround-suppression between and within hemifields Viola Störmer[1](vstormer@fas.harvard.edu), Patrick Cavanagh[1,2], George Alvarez[1]; [1]Vision Sciences Laboratory, Harvard University, [2]Laboratoire Psychologie de la Perception, Université Paris Descartes

Keeping track of multiple moving objects is an important aspect of visual cognition. Previous behavioral studies have shown that attention can select moving targets independently in the left and right visual fields (Alvarez & Cavanagh, 2005). Recent research indicates that one critical aspect of this hemifield effect is the requirement to spatially filter task-irrelevant information surrounding the targets (Alvarez, Gill, & Cavanagh, 2012). Here we tested whether there are differences in the efficiency of surround-suppression when attention is allocated to targets within a visual hemifield or between visual hemifields. We used an attentive tracking task that requires the continuous selection of one item from a pair of targets that orbited around a common center. Rotation speed thresholds for 80% accuracy were obtained for each individual and condition prior to the experiment. Threshold speeds for between-hemifield tracking were higher (better performance) relative to within-hemifield tracking. During the main experiment we recorded electrophysiological responses (ERPs) while observers tracked one target (unifocal), two targets that were presented between hemifields (multifocal bilateral), or two targets that were presented within a hemifield (multifocal unilateral). To directly assess surround suppression, we presented probe stimuli at a fixed location (within the top left quadrant) at a fixed distance from the target. We observed that the response to the probe was suppressed when participants tracked two targets in separate hemifields (left and right) compared to when participants tracked two targets within one hemifield. These findings show that surround-suppression operates more effectively during bilateral tracking relative to unilateral tracking. These differences in suppressive surrounds suggest that attention can be more sharply focused around each target when targets are in separate hemifields rather than in the same hemifield and that this is a likely mechanism contributing to the behaviorally observed hemifield effects in many spatial attention tasks.

63.307 Visual attention and willpower: Shared resources between ego depletion and multiple-object tracking? Aysu Suben[1](aysu.suben@yale.edu), Brian Scholl[1]; [1]Department of Psychology, Yale University

Vision science and social psychology each often appeal to a capacity-limited resource that involves a sense of mental effort: visual selective attention, and willpower. How do they relate? Might they reflect the same underlying resource, applied in very different contexts? Across several experiments, we explored the relationship between sustained attention (realized via multiple-object tracking; MOT) and willpower (realized in common manipulations and measures of ego depletion). In an initial set of experiments, Depletion subjects first wrote a story about a zoo trip, while avoiding thoughts about a white bear. They then followed a complex set of rules about how and when they should cross out instances of the letter 'e' in a text. Control subjects wrote about a zoo trip without extra constraints, and then simply crossed out each instance of the letter 'e' on a page, without complex rules. Half of the subjects from each group subsequently attempted to solve an impossible figure-tracing task. The other half completed a standard MOT task — keeping track of a subset of identical-looking but independently-moving objects for 10 s. Depletion subjects attempted to complete the figure-tracing task for less time than Control subjects (a standard ego-depletion effect). Depletion subjects also performed worse on MOT relative to Control subjects. We then explored whether MOT (using various tracking loads and durations) influenced subjects' subsequent figure-tracing persistence. It did not — even for relatively demanding varieties of MOT. These results (and those testing other aspects of attention) suggest that MOT may share resources with willpower, but in an asymmetric way: ego-depletion uses up resources that are needed for successful MOT, but MOT does not use up resources that are required for a type of self control. These and other results show how vision science may play a role in social psychology, and vice versa.

63.308 Exploring the Body Boundary: How visual attention treats stimuli on the hands Eric Taylor[1,2](j.eric.t.taylor@gmail.com), Jessica Witt[3]; [1]Purdue University, [2]University of Toronto, [3]Colorado State University

Attention operates in the space near the hands with unique, action-related priorities. Here, we examined how attention treats objects on the hands themselves. We tested two competing hypotheses. First, attention on the hands may exaggerate action-related priorities (e.g. faster detection of on-hand stimuli), as though the surface of the hands is the proximal case of near-hand space. Alternatively, we proposed the body boundary hypothesis: Attention should be biased to avoid orienting toward the hands (in order to remain entrained to near-hand space). We employed a spatial cueing paradigm to assess how attention is deployed to the surface of the hands. Stimuli were projected onto participants' hands such that detecting invalidly cued targets required shifting attention across the surface of the hands. We observed a delayed orienting of attention from near-hand space to the hand (Experiments 1A & 1B) and from hand to hand (Experiment 2). In contrast to typical findings in object-based attention, this delayed orienting also occurred when shifting attention within the space occupied by a hand (Experiment 3). Finally, we show that grasping a tool induced delayed orienting to the end of the tool, as though it were incorporated into the body boundary (Experiment 4). These results support the body boundary hypothesis. We suggest that the body boundary could assist the guidance of action by making attention predisposed to avoid orienting toward the hands and instead toward near-hand space, where the targets of actions are usually located.

63.309 Spatial attention selection guides object correspondence in apparent motion Yangqing Xu[1](xuy@u.northwestern.edu), Satoru Suzuki[1], Steven Franconeri[1]; [1]Northwestern University

Previous research has suggested a close link between apparent motion perception and attentive tracking (Cavanagh, 1992; Lu & Sperling, 1995). A strong version of this account predicts that shifts of spatial attention solve the correspondence problem. Consistent with this account, we show that spatial selection closely tracks objects during apparent motion, and that manipulating spatial attention can have a causal effect on apparent motion percept. In Experiment 1, participants were presented with a 6-frame ambiguous apparent motion display that could be perceived as either a yellow circle moving left and right, or two circles moving up and down separately on the left and right sides. By monitoring spatial attention with an electrophysiological correlate (N2pc, CDA/SPCN), we observed spatial selection synchronously tracking a single object in the direction of its apparent motion. In Experiment 2, participants viewed a 4-frame ambiguous apparent motion display that could be seen as two circles rotating clockwise or counter-clockwise. Eye movements revealed that participants spontaneously selected the top object and shifted selection in tandem with the perceived motion trajectory. In Experiment 3, we directed exogenous spatial attention by presenting a brief flash cue in the middle of a 2-frame ambiguous apparent motion display. The location of the cue systematically biased the perceived direction of rotation, and participants again tended to spontaneously track the top object. In Experiment 4, we required participants to endogenously attend to the top or the bottom object initially. Motion was perceived in the direction of selection shift driven by the exogenous cue, relative to the initial selection. We have thus demonstrated that spatial selection tracks an object during apparent motion and that spatial selection shifts determine the direction of apparent motion, providing compelling evidence that spatial selection can be an important agent in guiding the object correspondence in ambiguous apparent motion.

63.310 Are basketball players just dots? Comparing multiple object tracking in real and simple contexts Ashley M. Sherman[1](ashley.sherman@stonybrook.edu), Todd S. Horowitz[2], Horesh Ben Shitrit[3], Gregory J. Zelinsky[1]; [1]Department of Psychology, Stony Brook University, [2]National Cancer Institute, [3]CVLab, EPFL, Lausanne, Switzerland

It is often assumed that multiple object tracking (MOT) experiments can be generalized to real world tracking tasks. However, MOT experiments deliberately use impoverished stimuli; the typical MOT array is a set of identical dots following random trajectories in a plane. In contrast, realistic tracking situations allow observers to exploit knowledge about how objects should move in a given context as well as the distinguishing features of objects, which has been shown to improve tracking performance (Horowitz, et al., 2007; Makovski & Jiang, 2009). In Experiment 1, we asked whether observers can use contextual information to facilitate tracking. We obtained sixty-seven 20 s video clips of basketball games. We then employed tracking software (Ben Shitrit, et al., 2007) to generate matching clips consisting only of moving dots following players' trajectories. Half of the participants tracked basketball players, the other half dots. There were 2 or 4 targets (equally distributed across teams), designated by flashing green circles for 2 s. After 20 s of tracking, all players or dots were circled in blue and participants marked all targets via mouseclick. Tracking accuracy was superior with basketball videos (p <.05). This could reflect feature information, contextual knowledge, or both. In Experiment 2, we controlled for feature information by using 8-20 s videos of basketball games played normally, reversed, or inverted. The procedure was the same as Experiment 1, except that video condition was varied within-subjects. We found significantly higher accuracy for normal and reversed videos compared to inverted videos (p <.05), suggesting that tracking suffers when context violations make it difficult to predict motion. We conclude that in real world tracking tasks, people exploit contextual information about how objects (basketball players, in this case) move in order to improve tracking performance.

63.311 **Lost, but not forgotten: Extra guesses reveal knowledge of lost targets in multiple object tracking**

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A typical multiple object tracking task (MOT) requires participants to track some number of targets among a set of featurally identical nontargets. When targets and nontargets approach close to one another they can become confused, leading to errors. A simple model of MOT might expect that lost targets are lost completely —participants track the wrong item and now ignore the former target as though it is a nontarget. We investigated the possibility that participants may keep track of lost targets, hypothesizing that they are aware when hazardous close encounters lead to errors, and therefore, that they may track items not simply as targets or nontargets, but on a likely-target continuum. To test this hypothesis, we asked participants to first identify as many targets as originally assigned, and then to identify two more items —i.e. to make two additional guesses. Thus with four targets assigned, participants made six responses. On trials where an error was made in the set of the original four responses, the crucial question was whether additional guesses were made accurately at a significantly higher rate than would be expected by chance. They were. We also found that guessing was significantly better than chance when excluding trials in which participants may have used a proximity heuristic, i.e. selecting the nearest object to a previously selected one. Overall, our results suggest that observers may at times 'keep tabs' on targets that they suspect they may have confused with nontargets. These results have important implications for theories of tracking, generally supporting probabilistic mechanisms, and also implying that participants may sometimes track more objects than initially assigned.

63.312 **Multiple-object tracking across various fields of view**

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Multiple-object tracking involves monitoring the locations of a number of targets as they move among identical distractors. Previous work on multiple-object tracking was restricted to smaller fields of view (~20°). This study explored the effects of increasing the size of the field of view on multiple-object tracking. Twenty participants were required to track 1, 3, or 5 targets among 10 identical items across three fields of view (20°, 80°, and 120°) for an 8 second tracking interval. Field of view was blocked, though the number of targets varied randomly from trial to trial. As is usually seen in multiple-object tracking studies, tracking accuracy dropped with increases in the number of targets (p <.001) but it increased with the size of the visual field (p <.001). This result suggests that the visual indexing mechanism may be more attuned to tracking in fields of view more akin to what might be the case in daily life and not artificially small (and dense). With dense displays, it may be easier to confuse targets and distractors, and that may explain the differences seen. Differences between attentional mechanisms as used for making fine discriminations and attentional mechanisms as used for visual-motor coordination in tasks such as driving and team sports are discussed.

63.313 **Motion Factors other than spacing may affect MOT performance**

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Recent research[1][2] suggests that in the Multiple Object Tracking [MOT] task, object spacing may be the one primary factor affecting relative tracking performance. In this experiment, we examined this claim by presenting a simple MOT task within a rotating circular scene on a computer display. By rotating this scene at different speeds, we changed the speed and motion complexity of the moving objects without altering the average spacing between the objects. We used counterclockwise rotational speeds of 0, 8, 16, and 24 revolutions per minute, and used subjects' tracking accuracy in tracking four targets with eight distractors as a measure of relative difficulty. We found that tracking moving objects in a rotating scene is more difficult than in a non-rotating scene, and that tracking difficulty increases with rotation speed. In particular, subjects' performance dropped from an average of 3.5 targets successfully tracked for the no-rotation case to around an average of 2 targets tracked for the 24rpm rotation case. Since the average pairwise distances are the same across conditions, this suggests that at least some other factor besides spacing remains important to performance on the MOT task. References: [1] Franconeri, S., Jonathan, S. J., & Scimeca, J. M. (2010). Tracking Multiple Objects Is Limited Only by Object Spacing, Not by Speed, Time, or Capacity. Psychological Science, 21(920-925). [2] Franconeri, S., Lin, J., Pylyshyn, Z., Fisher, B., & Enns, J. (2008). Evidence against a speed limit in multiple-object tracking. Psychonomic Bulletin & Review, 15(4), 802-808.

63.314 **Tracking Deforming Items**

Piers Howe[1](pdhowe@unimelb.edu.au), Alex Holcombe[2], Mark Lapierre[1], Simon Cropper[1]; [1]Psychological Sciences, The University of Melbourne, Australia, [2]Department of Psychology, University of Sydney

Observers often need to keep track of moving items. Previous research has shown that tracking is much more difficult if the items appear to pour from one location to another in a substance-like manner, leading to the claim that observers can track objects but not substances (vanMarle & Scholl, 2003, Psychological Science, 14(5), 498). When a substance pours, it necessarily expands and contracts. Here we show that expansion and contraction per se inhibits tracking, regardless of whether the expansion and contraction is consistent with a substance-like movement. Four additional experiments identified two reasons why expansion and contraction inhibits tracking: 1) Items that expand and contract tend to overlap with each other and these overlaps make it hard to confine attention to just the subset of the items that the observer wishes to track. 2) Expansion and contraction create motion signals in the direction of the expansion and contraction. Such signals conflict with those motion signals that indicate in what direction the item is moving, i.e. the movement of its center. This reduces tracking accuracy, likely because it makes it harder for observers to predict the item's future location.

Acknowledgement: Supported by internal grants from the University of Melbourne

63.315 **Object Tracking via Spatiotemporal Continuity vs. Surface Features**

Samuel Harding[1](hardinsm@indiana.edu), Ty Boyer[2], Bennett Bertenthal[1]; [1]Department of Psychological and Brain Sciences, Indiana University, [2]Department of Psychology, Georgia Southern University

The individuation of objects via spatiotemporal continuity and surface features, such as texture and orientation, was studied with a streaming-bouncing paradigm. In a typical display, two moving discs start on opposite sides of the screen and move toward each other, coincide, and then reverse directions. If the discs share identical surface features, the perception of the event is ambiguous and the discs could be perceived as streaming or bouncing. If the discs are not identical, distinctive features could disambiguate this percept. The following experiments were designed to explore how surface features interact with spatial-temporal information and bias the percept toward streaming or bouncing. Four experiments were conducted in which participants judged whether the two discs (1.50 visual angle) streamed or bounced (constant velocity = 3.5 horizontal deg/sec) as they moved across a grey background. Between-subject variables included trajectory (horizontal vs. diagonal) and surface features (luminance gratings or random dots). The orientations of the gratings for the two discs differed by 0, 15, 30, or 45 deg; the probability density distributions for the random dots differed by 0, 10, or 20%. In each experiment, there were three conditions mediating the intersection of the two discs (occlusion, transparency, or visible occluder), which were programmed to bounce on every trial. Participants were presented with a total of 288 trials with 24 (luminance grating) or 32 (random dots) per intersection condition by surface feature difference (ΔF). Consistent with previous studies, the results revealed a significant bias to perceive streaming (on average 80% with $\Delta F=0$) in the transparent and occluder conditions, which decreased as a function of ΔF. By contrast, the likelihood of perceiving streaming in the occlusion condition rarely exceeded 30%. These results also interacted with trajectory and surface feature. Taken together, these results suggest that multiple processes are involved in individuating objects.

63.316 **Stereoscopy benefits processing of dynamic visual scenes by disambiguating object occlusions**

Jocelyn Faubert[1](jocelyn.faubert@umontreal.ca), Rémy Allard[1]; [1]Visual Psychophysics and Perception Laboratory, School of Optometry, Université de Montréal

How and to what extent stereoscopic cues help process dynamic visual scenes is still unknown. As we navigate in crowds or when we play sports we are often obliged to make rapid decisions in complex motion environments while attending to multiple elements. Stereoscopy can improve speed thresholds for a multiple object tracking (MOT) (Faubert & Sidebottom, 2012), but the nature of this advantage remains undetermined. From an attention perspective, there are at least two possible hypotheses to explain this advantage. One possibility is that stereoscopy reduces the attentional bottleneck as seen in 2-dimensional MOT environments (Intrilligator & Canavagh, 2001) by distributing attention uniformly in 3D space. Another hypothesis is that the stereoscopy helps attentional tracking by segregating the target and the non-target objects during occlusions. We have addressed these hypotheses by testing subjects with and without stereoscopic cues for different stimulus configurations in which pairs of spheres were rotating in orbit with one another in a 3D virtual space. In one set of conditions, object pairs rotated without ever occluding each other. In the second set of conditions, the objects occasionally occluded each other as they were rotating around an axis perpendicular to the observer. All conditions consisted of 4 pairs of spheres presented in each quadrant of the visual field at 20 degrees of eccentricity. Stereoscopy improved MOT speed threshold by a factor of about 3 when objects occluded each other, but slightly, yet significantly, impaired speed threshold by about 18% when objects did not occlude each other. We conclude that the overall benefit of stereoscopy for processing dynamic scenes comes from improved attention tracking by disambiguating targets from non-targets during occlusions. Conversely, stereoscopic cues were a disadvantage in absence of occlusions.

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63.317 **Perceived Size of a Moving Target** Alexandria Boswell[1](alexboo@gmail.com), Gennadiy Gurariy[1], Gideon Caplovitz[1]; [1]Psychology, University of Nevada, Reno

There is an extensive literature on size perception, but we know much less about the perception of motion trajectories. It is important we examine this more closely because perceiving trajectory size is not a trivial task. For example, Sinico et al. (2009) showed that people underestimate the size of a trajectory on which a dot is moving. In this study, we investigated how well people discriminate the size of a trajectory when compared to their size judgement of a stationary circle. In Experiment 1, we examined the perceived size of a trajectory of a dot moving 360° around a circular path. Experiment 2 examined how accurate people were at this task when the dot moved only a portion of the path, ranging from 90° to 355°. Experiment 3 examined accuracy when the dot moved in an arc exactly as in Experiment 2, but with the speed also randomized. Experiment 4 examined how accurately people judge the sizes of stationary circles with the same radii used to form the trajectories in the previous experiments. Results: people are less accurate at discriminating sizes across all motion conditions when compared to the stationary circle. They were even less accurate when the full trajectory was not transversed. Surprisingly, the speed of the traveling dot had little effect on participants' discrimination, which is interesting because one method of discrimination for this task is to use the speed of the moving dot to aid in the size judgement. This suggests that people are able to perform reasonably well on this task even without the aid of speed discrimination.

63.318 **Interactions between Global and Local Motions during Object Tracking** Bennett Bertenthal[1](bbertent@indiana.edu), Sam Harding[1], Rob de Ruyter[2]; [1]Department of Psychological and Brain Sciences, Indiana University, [2]Department of Physics, Indiana University

Object tracking was studied with a streaming-bouncing paradigm. In a typical display, two discs approach each other from the left top and bottom edges of the screen until they coincide, then change direction by 90 deg, and continue to the right top and bottom. If the discs share identical surface features, the perception of the event is ambiguous and could be perceived as streaming (discs pass through each other) or bouncing. If the discs are not identical, distinctive surface features could disambiguate this percept. The discs were comprised of random textures generated by applying an isotropic Gaussian filter to white spatial contrast noise, and subsequent normalization to a defined contrast variance. For one disc, the local direction of texture motion was either the same or opposite its direction of global motion, whereas the local direction of the other disc was oriented (+/-) 0, 15, 30, or 45 deg relative to the first disc. The two discs intersected via occlusion or transparency. Participants fixated a cross in the center of the screen throughout the trial and reported whether the two discs "streamed" or "bounced." There were a total of 192 trials with 24 per intersection by texture motion condition. Consistent with previous studies, there was a strong bias to perceive the discs streaming although this response decreased as the difference in the direction of the local motions increased. The perception of streaming was significantly greater when the local motions moved in the same as opposed to the opposite direction of the discs. In previous studies with occlusion at the intersection and static textures, streaming was reported at a rate of 20%, whereas it was typically above 50% in this study. Taken together, these results suggest that the perception of local motions interact with the perception of global motions while tracking objects.

63.319 **Multiple Object Tracking: Support for Hemispheric Independence** Daryl Wilson[1](daryl.wilson@queensu.ca), Michael O'Grady[1], Jason Rajsic[1]; [1]Psychology Department, Queen's University

Using a variant of the multiple object tracking paradigm, Alvarez and Cavanagh (2005) showed that as the task became more demanding, tracking performance was significantly more accurate when targets were distributed between the left and right hemifields compared to when they were presented within a single hemifield. Based on this result, they proposed a hemispheric independence capacity account suggesting that there are independent resources for tracking in each hemifield. In the current study, we tested an alternative distribution account which suggested that the spatial distribution of the tracked objects was the factor underlying their results. In sixteen conditions, we manipulated the distribution of the targets (vertical or horizontal), the positioning of the distribution (within one side, both sides central, or both sides peripheral), the motion of the targets (within- or cross-hemifield), and the number of tracked objects (2 or 4). While the distribution of objects had a small influence on tracking performance, the largest factor influencing tracking performance was whether all stimuli were presented within the same hemifield or not. In sum, the results were largely inconsistent with the distribution account and provided support for the hemispheric independence account.

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63.320 **Hemifield asymmetries in attention-based motion discrimination** Leslie Welch[1](leslie_welch@brown.edu), Nestor Matthews[2]; [1]CLPS Dept, Brown University, [2]Psychology Department, Denison University

Introduction: Previous research has shown performance asymmetries between right and left hemifields on attention-based tasks with a disadvantage for right visual field (RVF). For example, Battelli et al. (2007) reviewed evidence for worse performance in RVF on high-level motion tasks. Which aspects of spatiotemporal processing could be responsible for the performance difference? Method: Twenty-one Denison University undergraduates viewed pairs of Gabor targets within the same hemifield. Targets changed orientation either simultaneously or at various asynchronies. Temporal order judgments (TOJ) and simultaneity judgments occurred in separate blocks with the order counterbalanced across participants. A second group of twenty-three students viewed Gabor target pairs where one or two Gabors changed orientation, and their task was to indicate how many changed (1 vs 2 task). A third group of eighteen students viewed Gabor target pairs that flickered in counterphase, and they judged which Gabor flickered faster (TF discrimination). Results: TF discrimination and counting the number of orientation changes (1 or 2) thresholds were the same for RVF and LVF targets. Hidden formatting deleted. Delete this text! yes"> However, TOJ and simultaneity thresholds both showed worse performance for RVF targets compared with LVF targets. Conclusions: No hemifield difference in TF discrimination thresholds argues against coarser temporal sampling in RVF, suggesting no difference in quality of the front-end detectors. No difference in the 1 vs 2 task argues against hemifield differences in counting transients, suggesting simple comparisons are equivalent. Both simultaneity and TOJ require more information than the other tasks about when and where transients occurred, implicating a motion-attention stage.

Object recognition: Reading

Wednesday, May 15, 8:30 am - 12:30 pm

Poster Session, Royal Ballroom 6-8

63.321 **Units of word recognition** Xavier Morin Duchesne[1](xavier.morin.duchesne@umontreal.ca), Daniel Fiset[2], Martin Arguin[1], Frédéric Gosselin[1]; [1]Centre de Recherche en Neuropsychologie et Cognition, Département de Psychologie, Université de Montréal, CP 6128, succ. Centre-ville, Montréal, H3C 3J7, CANADA, [2]Département de Psychoéducation et de Psychologie, Université du Québec en Outaouais, CP 1250, succ. Hull, Gatineau, J8X 3X7, CANADA

Last year at VSS, we showed that the word feature asymmetry, a high concentration of features leading to recognition in the upper half of words (Huey, 1908; Blais et al., 2009; Perea et al., 2012), cannot be accounted for by the distribution of features used in letter recognition and, thus, that words are not read by letters. We also reported a significantly smaller asymmetry towards the upper half of nonword trigrams. We hypothesised that constructs common to words and nonword trigrams were driving this asymmetry. Preliminary analyses identified two candidates: lexical trigrams and syllables. Our aim, here, was to investigate further these possible units of word recognition. Twenty observers were presented with two- and three-letter syllables (as defined in Lexique 3, New et al., 2001), as well as lexical bigrams and lexical trigrams (sequences of two or three letters found within words from Lexique 3 that are not syllables), and their non-lexical counterparts. Stimuli were blocked and presented in Arial lowercase, partially masked. The mask originated from the bottom or top and hid from 1/6 to 5/6 of the stimulus. We found that both syllabic stimuli, as well as the lexical bigrams and trigrams presented an asymmetry towards the upper half. We also found that none of these could be accounted for using the single letter data. Finally, syllables presented a significantly greater asymmetry than the lexical bigrams and trigrams. We will be discussing the implications of these findings for the units of word recognition.

63.322 **Using abbreviations to increase reading speed in low vision**

Steve Mansfield[1](mansfijs@plattsburgh.edu), Katie Tifft[1], Pei Ning Lee[1], Stephanie Crocco[1], Jordan Wendling[1]; [1]Psychology, SUNY College at Plattsburgh

Introduction: Low vision often slows reading because visual impairments limit how many letters can be recognized in each glance. We have investigated whether this limitation could be alleviated using abbreviations. Abbreviations reduce the redundancy in printed English, so that the information is conveyed by fewer letters. We anticipate an improvement in reading speed commensurate with the reduction in text length. Methods: We measured the reading-speed benefit of abbreviations for 64 students reading with simulated acuity loss (wearing blurring goggles that, on average, increased acuity print size from 0.04 logMAR to 0.65 logMAR), and for four students reading with simulated visual-field loss (the display was restricted so that only ½, 1, 2, 4, or 8 characters were visible at a time — the reader used the computer mouse to navigate through the text). Reading speed was measured for sentences that included many numbers that were either written as words (e.g., "twenty-three") or which were abbreviated by using their digit form (e.g., "23"). Using digits in this way was convenient for this study: they are familiar, easy to read, and they substantially reduced the length of the sentences. Results: The blurring goggles slowed reading speeds for the full-length texts by 40%, but with the abbreviations this deficit was reduced to 25% ($p<0.05$). Similarly, reading with the ½-character window slowed reading speeds for the full-length texts by 60%, but with the abbreviations this deficit was completely eradicated ($p<0.001$). Conclusion: These findings suggest that abbreviations could produce substantial reading speed gains for people with low vision. The search is now on for an abbreviation scheme that can realize these benefits in everyday reading materials.

63.323 **Uncrowding the Visual Span: Does It Improve Reading?**

Yingchen He[1](hexxx340@umn.edu), Gordon Legge[1]; [1]Department of Psychology, University of Minnesota

The visual span for reading is the number of text letters that can be recognized accurately without eye movements, and is hypothesized to be a sensory bottleneck limiting reading speed. It has been shown that the size of the visual span in peripheral vision can be enlarged through training on a letter-recognition task. This enlargement is accompanied by an increase in reading speed, and is primarily due to a reduction in the crowding effect (He & Legge, VSS, 2012). However, the proposed linkage between reading speed, visual span, and crowding appears to be inconsistent with a dissociation between crowding and reading speed (Chung, Vision research, 2007). Chung found that after training on identifying crowded letters in peripheral vision, the spatial extent of crowding was reduced without significantly increasing maximum reading speed. To address this discrepancy, we repeated but modified Chung's uncrowding training: whereas Chung trained subjects to recognize flanked letters on the midline at 10 deg in the lower visual field, we moved our training 3 letter spaces leftward, where the impact of crowding on visual span is larger than on the midline. Training consisted of four days of the flanked-letter recognition task, approximately 1500 trials/day. In pre- and post-tests, visual span profiles, RSVP reading speed and the spatial extent of crowding were measured at 10 deg in the lower visual field. Consistent with Chung, we found a significant reduction of the spatial extent of crowding. Unlike Chung, our training significantly enlarged the visual span by 3.1 bits and improved the reading speed by 18%. Our results suggest that when uncrowding training is performed at a location where crowding has a more profound effect on visual span, the training can both enlarge the visual span and increase the reading speed, supporting the linkage between reading speed, visual span, and crowding.

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63.324 **Predicting reading performance for different fonts using physical and perceptual properties of letters**

Jean-Baptiste Bernard[1](jb.bernard@berkeley.edu), Daniel R. Coates[2], Susana T. L. Chung[1,2]; [1]School of Optometry, UC Berkeley, [2]Vision Science Graduate Program, UC Berkeley

Previous studies have reported differences in reading speed depending on the font used. The dependence of reading speed on letter recognition (Legge et al, 2001) predicts that poor letter recognition performance would lead to low reading speed. In this study, we investigated if physical attributes of letters and/or perceptual properties of letter recognition can predict reading performance for different fonts. Reading speed was measured using the rapid serial visual presentation paradigm, for a range of print sizes (x-height: 0.7° – 2.8°) and for 13 different fonts in 8 subjects. For each font, we derived the two most important characteristics that summarize the reading performance: the maximum reading speed (MRS) and the critical print size (CPS), the smallest print that can be read with maximum speed. The letter size that enabled subjects to identify single letters at 80 percent-correct at 100ms was also determined ("letter acuity"). For each font matched in x-height, the following physical attributes of letters were measured based on font letter templates: x-width, average letter width, average letter height, ink area, skeleton length, perimeter, perimetric complexity, stroke width, inter-letter similarity and stroke regularity. Principal Component Analysis was performed to extract the principal components that captured the physical variations across fonts. Averaged across subjects, CPS (range: 0.09° – 0.16°) and MRS (range: 459 wpm – 713 wpm) were different across fonts. Principal components of the physical attributes failed to predict CPS and MRS using a multiple regression model (adjusted $R2<0.14$). However, there was a correlation between letter acuity and CPS ($r=0.94$; $p<0.001$), and between letter acuity and MRS ($r=-0.80$; $p=0.03$). Our results suggest that linear relations of physical measurements are not able to predict the differences between reading speeds across fonts. However, letter acuity, a perceptual measure, seems to be a good predictor of maximum reading speed.

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63.325 **Effect of Complexity on the Visual Span for Chinese and Alphabetic Characters**

Hui Wang[1](wang1281@umn.edu), Xuanzi He[2], Gordon Legge[3]; [1]Department of Biomedical Engineering, College of Science and Engineering, University of Minnesota, [2]Department of Educational Psychology, College of Education and Human Development, University of Minnesota, [3]Department of Psychology, College of Liberal Arts, University of Minnesota

The visual span for reading is defined as the number of adjacent letters that can be correctly identified without eye movements, and may impose a sensory bottleneck on reading speed. In this study, we extended the concept of visual span to Chinese characters. We investigated the effect of complexity on the size of the visual span for alphabetic and Chinese characters, and explored the sensory factors contributing to the differences we observed. Perimetric complexity was used to quantify the complexity of binary character images and classify them into four complexity groups (26 characters per group), including lower case alphabetic letters and three Chinese character groups. Six normally sighted bilingual subjects participated. Subjects were asked to recognize trigrams (3 adjacent characters) presented randomly at 17 positions left and right of fixation. Visual span profiles were constructed as recognition accuracy vs. character distance from fixation. The size of the visual span was quantified as the width of the profile (number of characters) at 80% correct. As complexity increases visual span decreased from 10.7 characters for alphabetic characters to 5.0 for the most complex Chinese characters. We also measured the visual span for isolated characters. By comparing recognition profiles for isolated characters and trigrams, we estimated the effects of acuity (decline in recognition away from fixation for isolated characters), crowding (difference between the profiles for isolated characters and trigrams) and mislocations (correct recognition at the wrong position within a trigram). We found that crowding is the major factor limiting the visual span and significantly increases with complexity. There is a smaller effect of mislocation, which is greater for Chinese character recognition. We conclude that visual spans for Chinese characters are narrower than the visual span for alphabetic letters, primarily due to increased crowding associated with the greater complexity of the Chinese characters.

Acknowledgement: NIH Grant R01 EY002934

63.326 Coarse-to-fine spatial analysis for identifying multiple letters? Susana T. L. Chung[1,2](s.chung@berkeley.edu), Girish Kumar[1], Daniel R. Coates[2]; [1]School of Optometry, UC Berkeley, [2]Vision Science Graduate Program, UC Berkeley

The analysis of visual stimuli is widely believed to follow a coarse-to-fine time course. This theory predicts that when humans identify groups of letters, the identification error rate and the pattern of errors (e.g. errors consistent with the global shape or the fine details of letters) would be different for short vs. long stimulus presentation durations. We tested these predictions by comparing the error rate and the pattern of the errors (based on confusion matrices corrected for observer bias) made by three observers who identified all letters presented in trigrams (sequences of three random lowercase letters, x-height=1.2°, letter separation=2.4°), for stimulus exposure durations of 50 and 200 ms. The center of each trigram was presented at 10° in the lower visual field. To examine the effect of spatial scale, letters were filtered using 1-octave raised-cosine log filters centered at 1.35 or 5 c/letter. Testing was also performed for unfiltered letters. 1300 trials were collected for each observer and for each condition. Contrary to our prediction, error rates (overall, or for each letter position) were highly similar between the two spatial-frequency conditions, which were 3–4x higher than the corresponding error rates for the unfiltered condition. Error rates were also higher for the 50-ms than the 200-ms condition. Interestingly, proportion of mislocation errors were ~2x higher for the unfiltered than for the two filtered conditions. When trials with mislocation errors were excluded, the identification errors made were consistent with observers relying on the global shape of letters for making judgment (e.g. confusions among round letters {aceos}), regardless of the spatial-frequency content or the duration. The similar error rate, and the similar pattern of identification errors made for the two spatial-frequency filtered conditions suggest that humans rely on a set of cues to identify letters that are invariant to different scales of analysis.

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63.327 Fast and slow temporal integration in visual word recognition: A demonstration of the Presentation of Parts in Noise (POPiN) paradigm Ronald Chu[1](ron.chu@mail.utoronto.ca), Steve Joordens[1]; [1]Psychology, University of Toronto

The visual system is constantly bombarded with continuous streams of information. As such, a primary challenge in visual perception is determining which stimuli should be integrated or segregated across time. Take the example of a film being presented at the standard rate of 48Hz. Subjectively, we perceive the individually presented frames as a continuous stream of information. However, if that film strip is slowed to a presentation rate of 1Hz, we then perceive the frames as individual units. Critically, there seems to be a threshold presentation rate that characterizes a shift in the perception of the film as continuous stream of information to the perception of segregated frames. This study focused on the temporal integration of visual word recognition. The experiments employed a novel word identification paradigm wherein target words were broken down into parts and presented, with noise, along a rapid serial visual presentation (RSVP) stream (e.g., HXMX, XOXE, XOMX, HXXE, would be a typical presentation stream for the target word 'HOME'). Experiment 1 demonstrated that changing the presentation rate (43Hz, 22Hz and 11Hz) of the RSVP stream led to qualitatively different approaches to target integration. At fast rates, all target letters were integrated automatically. However, at slow rates, target identification necessitated a conscious, 'string building' strategy. Experiment 2 validated the claim for qualitatively different approaches to integration; performance on a concurrent working memory task was impaired only at the slow presentation rates. Together, the results suggest that temporal integration in visual work recognition works according to ~100ms integration windows. Integration beyond that window is still possible, but necessitates top-down working memory influences.

63.328 The components and modality-specificity of word representations in the human visual system: an adaptation study Diana Choi[1,2,3](diana.choi@mail.utoronto.ca), Hashim Hanif[1,2], Charlotte Hills[1,2], Jason J S Barton[1,2]; [1]Department of Ophthalmology and Visual Sciences, University of British Columbia, [2]Department of Medicine (Neurology), University of British Columbia, [3]Department of Medicine, University of Toronto

Background: While many studies have used adaptation to probe the neural representation of faces, few have used this to examine how words are represented in the human visual system. Last year we established that word aftereffects exist and are invariant for script style (Hanif et al, J Vis 2012: 12(9): 1060). Objective: Our goals were, first, to use adaptation to examine the contribution of components of words to the word aftereffect and second, to determine if there was cross-modal transfer of aftereffects. Methods: 30 subjects participated in Experiment 1. Two pairs of compound words of equal length were chosen as base stimuli, in upper case Arial font. Ambiguous probe stimuli were created by merging different degrees of transparencies of the pairs together in an overlay, with added Gaussian noise. The 5-second adapting stimuli were either the original words, words with the component morphemes re-arranged, or a rearrangement of the original words' letters into a meaningless string. 12 subjects participated in Experiment 2. Two pairs of words were chosen. Probe stimuli were generated by either the same method, or a morphing procedure, for comparison. In the visual condition, the original words were presented as 5-second adapting stimuli, while in the auditory condition, the adaptor was a 4.8-second tape of different individuals saying the original word every 800ms. Results: Experiment 1 generated a 17% aftereffect for whole words, while the re-arranged morphemes generated a small 5% aftereffect, and letter strings generated no aftereffect. Experiment 2 generated a 10% aftereffect for whole visual words, irrespective of probe type, but no aftereffect from auditory words. Conclusion: Visual words have a strong representation at the whole-word level, and a minor grapheme component. As found previously for face expression and age aftereffects, there was no cross-modal transfer from the auditory sense.

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63.329 Representation of word parts and wholes in occipitotemporal cortex Alexandra Coros[1, 2](lexcoros@gmail.com), Lars Strother[1, 2], Tutis Vilis[1, 2]; [1]Brain and Mind Institute, University of Western Ontario, [2]Department of Physiology and Pharmacology, University of Western Ontario

We used fMRI to study the cortical representation of words that were split in half between right and left visual hemifields (split at fixation). We measured fMRI responses to words that repeated or changed in one of four possible ways: (1) the whole word repeated; (2) the whole word changed; (3) the left (but not the right) half of the word changed; or (4) the right (but not the left) half of the word changed. We observed substantially decreased fMRI responses to repeated stimuli relative to words that changed (fMRI adaptation) in occipitotemporal cortex (OT), including the 'visual word form area' (VWFA) and the 'occipital face area' (OFA) in posterior OT. We observed maximal adaptation in the VWFA and bilateral OFA. The VWFA adapted to whole-word repetitions and the OFA adapted to both whole-word repetitions and contralateral half-word repetitions. The exclusive whole-word adaptation effect was unique to the VWFA in left OT; whole-word adaptation was not observed in a putative right OT homologue. Adaptation to contralateral half-word repetitions was maximal in the right OFA and observed to a lesser degree in left OFA. Early visual areas showed equivalent fMRI responses to half-word repetitions. A second experiment showed that, in addition to whole-word adaptation, only the VWFA in left OT showed stronger fMRI responses to four-letter words versus non-word strings of similar retinal size and visual complexity. We conclude that posterior portions of OT represent word parts and the VWFA in left OT represents words as whole units. The VWFA is thus functionally distinct from other more posterior portions of OT that also respond strongly to word stimuli, such as the OFA.

63.330 Hemispheric lateralization of visual word and face activation in the fusiform gyri Jodie Davies-Thompson[1](jdthompson@eyecare-centre.org), Samantha Johnston[1], Yashar Tashakkor[1], Raika Pancaroglu[1], Jason J.S. Barton[1]; [1]Departments of Medicine (Neurology), Ophthalmology and Visual Sciences, University of British Columbia, Vancouver, Canada

Background: Visual words and faces activate similar networks and particularly regions in the fusiform gyri, but with complementary hemispheric asymmetries, faces being lateralized more to the right hemisphere, and words to the left hemisphere. It has been suggested that this reflects developmental competition for neural resources between visual word and face processing, possibly with word lateralization occurring first and driving face lateralization later (Dundas et al, J Exp Psychol Gen 2012, oi: 10.1037/a0029503). Objective: Our goal was to investigate whether such competition was reflected in an inverse correlation between the degree of lateralization of visual word and face activation in the fusiform gyri in a given subject. Methods: 26 literate right-handed healthy adults underwent a functional MRI program with a dynamic face localizer and a word localizer. First, cluster size and peak responses of the visual word form areas and fusiform face areas in the left and right hemispheres were examined, and a lateralization index derived. These indices were then correlated across subjects, between visual words and faces. Second, the analysis was repeated for all face- and word-selective voxels in the inferior occipitotemporal cortex. Results: There were no significant negative correlations between the lateralization indices of visual words and faces, in either the individual regions of interest or the inferior occipitotemporal cortex as a whole. Conclusion: If developmental competition between visual words and faces exists, this is not reflected in a complementary relationship between visual word and face activation in right-handed adults. This suggests the existence of other, perhaps more dominant factors that generate lateralization of function.

Acknowledgement: CIHR grant MOP-106511

Scene perception: High level

Wednesday, May 15, 8:30 am - 12:30 pm

Poster Session, Orchid Ballroom

63.401 Interaction Between Visual and Conceptual Processing in Art Appreciation

Gabriela Duran[1,2](psych.engineer@gmail.com), Mary A. Peterson[1]; [1]University of Arizona, [2]Universidad Autonoma de Ciudad Juarez

Understanding the interaction between titles and artworks can both increase our understanding of artistic appreciation, and reveal how semantic and visual processing interact. Previous studies had shown that in contrast with descriptive titles, elaborative titles increase understanding of artwork (Mills, 2001; Leder, Carbon, Rispas, 2006). However, there is no consensus on the impact of elaborative titles on liking and interest, essential components of art appreciation. For the present study we measured the effect of elaborative titles on liking and interest using John Gutmann's artistic photographs and their corresponding elaborative titles. In Experiment 1 art novices rated photographs with either (1) elaborative titles, (2) descriptive titles (developed by the researcher), or (3) without titles (counterbalanced across participants) during two blocks. Ratings from the first block showed that images with elaborative titles ($p = .036$) or without titles ($p = .003$) were rated as more interesting and were liked more than images with descriptive titles, demonstrating that redundancy of semantic information from image and title reduced art appreciation. There were no differences between the elaborative and the without-title conditions ($p =.449$) showing that elaborative titles did not necessarily increase participants' appreciation of photographs. Ratings were reduced from the first to the second exposure ($p =.045$). In Experiment 2, art novices first rated all photographs without titles, and then rated them again either without titles or with descriptive or elaborative titles. Under these conditions, photographs with elaborative titles were rated as more interesting than photographs with descriptive ($p = .012$) or without titles ($p <.001$), although they were not liked more ($p = .203$). That conceptual information in elaborative titles increases interest across repetition but does not necessarily increase liking suggests that different mental processes support interest in and liking of art.

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63.402 Visual-object working memory affects aesthetic judgments

Aleksandra Sherman[1](aleksandrasherman2014@u.northwestern.edu), So Yum Lim[1], Marcia Grabowecky[1], Satoru Suzuki[1]; [1]Psychology, Northwestern University

An important line of research within empirical aesthetics has been to determine how specific physical features, such as complexity, influence art preference. Researchers have hypothesized that art preference follows an inverted-U function of complexity, in that people tend to like art with increasing visual complexity up to a certain level, at which point preferences drop. However, what determines the peak complexity of the inverted-U function remains unknown. Here, we demonstrate that the inverted-U relationship depends on visual-object working memory (VOWM). Participants rated the complexity of 120 images of fine art in three blocks of presentations: upside-down for 50 ms, upright for 500 ms, and upright self-paced. We reasoned that viewing 50-ms upside-down images would provide minimal content information encouraging participants to judge visual complexity, whereas viewing 500-ms or self-paced upright images allowed participants to consider semantic factors in the complexity judgment. Participants subsequently rated all images on aesthetic preference. At the end of the experiment, VOWM and verbal working memory (VWM) were assessed in separate n-back tasks; VOWM was measured using pictures consisting of random 4-by-3 arrangements of gray-scale squares, and VWM was measured using words. We found that VOWM, but not VWM, correlated with preference for complexity in art. Individuals with higher VOWM preferred complex art more and simple art less, with the most preferred level of complexity elevated in individuals with higher VOWM. Importantly, these relationships were obtained only for the complexity ratings on the 50-ms upside-down images, but not for complexity ratings on the 500-ms or self-paced upright images, indicating that VOWM influences aesthetic appreciation of visual complexity (i.e., not semantic complexity). Specific visual features that promote art preference have been previously identified, but our result highlights the idea that influences of these features are systematically modulated by individual variations in visual-object working memory capacity.

63.403 Specifying the relationships between objects, gaze, and descriptions for scene understanding

Kiwon Yun[1](kyun@cs.stonybrook.edu), Yifan Peng[1], Hossein Adeli[2], Tamara Berg[1], Dimitris Samaras[1], Gregory Zelinsky[1,2]; [1]Department of Computer Science, Stony Brook University, [2]Department of Psychology, Stony Brook University

The objects that people choose to look at while viewing a scene provide an abundance of information about how a scene is ultimately understood. In Experiment 1, participants viewed a scene for 5 seconds, then described the scene's content, with this description being our estimate of their scene understanding. There were 104 scenes (selected from SUN09), spanning 8 scene types, and analyses were limited to 22 categories of common objects for which bounding box information was available. In Experiment 2, participants viewed 1000 scenes (from PASCAL VOC), each for 3 seconds, in anticipation of a memory test. Analyses were limited to 20 object categories and descriptions were obtained using Mechanical Turk. For both experiments, we found that fixated objects tended also to be described (95.2% for PASCAL, 72.5% for SUN09) and described objects tended also to be fixated (86.6% for PASCAL, 73.7% for SUN09). Differences between experiments were likely due to the PASCAL images being less cluttered than the SUN09 images, thereby increasing the probability of fixations on selected objects. People also tended to look more often at animate objects (people, animals) or objects that conveyed animacy (televisions, computer monitors) than inanimate objects (e.g., tables, rugs, cabinets). Furthermore, by analyzing where fixations typically fell within the bounding boxes for different categories of objects (using object-based fixation density maps), we were able to discern distinct category-specific patterns of fixation behavior. For example, fixations on tables and chairs tended to be distributed in the extreme upper halves of bounding boxes, reflecting the fact that things usually sit on these objects, whereas fixations on cats and cows were distributed along the horizontal midline, reflecting a center-of-mass looking bias. Collectively, these findings suggest that embedded in viewing behavior is information about the content of a scene and how a scene is being understood.

Acknowledgement: NSF Award #1161876

63.404 SceneNet: A Perceptual Ontology Database for Scene Understanding

Ilan Kadar[1,2](ilankadar@gmail.com), Ohad Ben-Shahar[1,2]; [1]Computer Science Department, Ben-Gurion University of the Negev, Israel, [2]The Zlotowski Center for Neuroscience, Ben-Gurion University of the Negev, Israel

Scene recognition is a fundamental problem in visual perception and yet scene understanding research has been limited by the lack of proper knowledge of visual scene ontology, and by the absence of meaningful scene representation. While recently we proposed a new experimental paradigm for defining and determining perceptual relationships between scene categories (Kadar & Ben-Shahar, 2012), here we introduce "SceneNet" - a new and comprehensive ontology database of scene categories derived directly from a large-scale human vision study that organizes scene categories according to their perceptual relationships. This ontology database suggests that perceptual relationships do not always conform to the semantic structure between categories, and provides a lower dimensional perceptual space with "perceptually meaningful" Euclidean distance, with each embedded scene category being represented by a single prototype. We also incorporate the SceneNet ontology into a computational scheme for learning non-linear mapping of scene images into the perceptual space, where each scene image is closest to its category prototype than to any other prototype by a large margin. In addition to much better computational results on various large scale scene understanding operations, the SceneNet database provides important insights into human scene representation and organization and may serve as a key element in better understanding of this important perceptual capacity.

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63.405 Measuring information acquisition during viewing of dynamic scenes using free, natural-language descriptions

Daniel R. Saunders[1](daniel_saunders@meei.harvard.edu), Peter J. Bex[1], Russell L. Woods[1]; [1]Schepens Eye Research Institute, Massachusetts Eye and Ear, Boston, MA

Most visual experience consists of dynamic natural scenes, but few tools are available for directly assessing the information that can be obtained from such experience. It would be valuable to have a measure sensitive to the

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richness of natural viewing as well as viewing of movies and television, and capable of registering failures of higher-order visual function such as object recognition and face perception. We have developed a method for evaluating perception of dynamic natural scenes, where participants supply a free, natural-language description of the content of a video clip, one of 200 video clips of 30 s duration drawn from dramatic and documentary films, and these descriptions are scored against a normative database. One normative database was collected using Amazon.com's Mechanical Turk (4000 responses, 99 participants), while another was collected locally (2400 responses, 60 participants) with recruitment stratified by age, including a 70y+ group. Several scoring algorithms derived from computational linguistics were evaluated, based on their ability to match descriptions to their corresponding clip. The best algorithm, a simple average of words shared with the normative descriptions, correctly matched 95% of the Mechanical Turk and 75% of the in-lab descriptions. The measure was further evaluated by showing Mechanical Turk participants (N = 92) clips which had been degraded by Gaussian blur, and by showing in-lab participants (N = 15) unmodified clips viewed through varying levels of optical defocus. In both conditions, the average free description score decreased as viewing conditions were degraded. Therefore, this measure can detect differences in information acquisition. The method could easily be adapted to evaluate specific hypotheses about sensory acquisition of high-level information.

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63.406 Rapid semantic categorization of scenes: an advantage for emotional images? Tiffany S Pan[1](tiffanypan19@gmail.com), Anne T Sokolich[1], Patricia Lin[1], Samy Abdel-Ghaffar[1], Sonia J Bishop[1]; [1]Dept. Psychology & HWNI, UC Berkeley

Over recent years, there has been increasing evidence that substantial information can be extracted from a mere glance at a natural scene (Rousselet et al., 2005; Fei-Fei et al., 2007; Greene & Oliva, 2009). Free-response data has indicated that while low-level sensory detail predominates at very short presentation times, accurate semantic information can frequently be extracted by 100msec (Fei-Fei et al., 2007). Experiments requiring categorization of scenes as members of a target category have meanwhile indicated that basic or super-ordinate level semantic categorization can be achieved with presentations of 12-60 msec (Rousselet et al., 2005; Greene & Oliva, 2009). Within the emotion literature, it has been argued that we are evolutionarily prepared to rapidly extract information about the presence of potential threat (Ohman & Mineka,2001). The extent to which image emotionality impacts the rapid semantic categorization of natural images, has not however been studied. Here, we tested the hypothesis that there would be an advantage for 'prepared' stimuli (i.e. animate highly arousing negative stimuli) in semantic categorization at brief presentation durations. Participants were asked to categorize positive, negative and neutral images as 'people', 'animals', 'objects', 'vehicles', 'food' or 'scenes' and rate them for arousal (emotional intensity). Each image was presented for 17, 33 or 100msec prior to backward masking. A texture-synthesis algorithm was used to create masks from the test-set images (Portilla & Simoncelli, 2000; Greene &Oliva, 2009). Categorization performance was above chance by 33msec presentation time, and at ceiling by 100msec. Analysis of the 33msec data using logistic regression revealed a three-way interaction between emotional valence, arousal, and animacy. If the image was positive or negative, highly arousing, and animate, the likelihood of categorizing the image accurately increased. Our data hence suggest that not only negative but also positive high arousal animate stimuli show prioritized perceptual processing, facilitating semantic categorization at short presentation durations.

63.407 Testing the influence of stimulus variability on visual memory for scenes Benjamin A. McDunn[1](bmcdunn@uga.edu), James M. Brown[1], Siddiqui P. Aisha[1], Ralph G. Hale[1]; [1]Department of Psychology, The University of Georgia

A widely reported scene perception phenomenon, boundary extension (BE), has been shown in visual memory reports for subjects recently presented an image or series of images. BE is characterized as a bias to consistently remember images as being more wide-angle than what was actually seen, possibly due to a source-monitoring error in which expectations based on scene characteristics are remembered as being part of the original sensory view (Intraub, 2011, 2012). Previous studies on BE typically present a series of images to be remembered, and then test these memories by presenting the same images again, or closer or wider-angle versions, and having subjects respond if the images are the same, closer, or wider-angle. Given that the phenomenon of interest is measured by responses concerning the perceived viewing distance in the stimuli, it is important to give attention to the variability in the scenes being presented. In previous studies, depicted main objects often exhibit extreme diversity in real world size; for example, objects vary from a candlestick to a car in Intraub and Richardson (1989). This size difference determines the perceived viewing distance from the main object in each image. For this study, we report experiments using scene stimuli presented in this traditional paradigm featuring more rigorous control of potentially confounding image features. The scenes used here depict objects of similar retinal and schematic size, a consistent background gradient across images, and the same viewing distance for each image. Manipulations of the difference between close and wide-angle image versions and other variables were performed. The results suggest that BE may not be as consistent as previous literature would suggest, yielding data that indicates no extension occurs under certain conditions using depictions of scenes.

63.408 Capture by object exemplars during category-based search of real-world scenes Katharina N. Seidl[1,2](kseidl@princeton.edu), Nicholas B. Turk-Browne[1,2], Sabine Kastner[1,2]; [1]Department of Psychology, Princeton University, [2]Princeton Neuroscience Institute, Princeton University

Unexpected objects capture attention to the extent that they match a currently active attentional set. This contingent attentional capture has been demonstrated for relatively simple features and for conceptual information when the distractor is disqualified from being a target only because of its spatial location. Here we ask whether exemplars from an object category capture attention during preparation for real-world visual search. This form of category-based search has been shown to depend upon establishing an abstract attentional template that enables efficient target processing through the pre-activation of category-specific neural representations. Participants completed a category detection task in which they were asked to detect the presence of objects from a specific category in centrally presented and masked real-world scenes. At the beginning of each trial, a cue informed participants which of two task-relevant categories to attend to. The possible task-relevant categories were people, cars and trees, which were counterbalanced across participants. Scenes could contain objects from: the cued category, the non-cued task-relevant category, both task-relevant categories or none of the task-relevant categories. On 75% of the trials a distractor was presented 150 or 600ms before the scene. Distractors consisted of exemplars from the cued category (congruent), the non-cued task-relevant category (incongruent) or from a task-irrelevant category (neutral). They were presented either centrally or in the periphery. At short but not long SOAs, the presence of a congruent distractor reduced accuracy on the category detection task more than any of the other distractor categories. This indicates overlap between attentional sets for within-scene objects and isolated exemplars. The capture effect was observed regardless of distractor location, suggesting that reduced search accuracy did not only result from the deployment of spatial attention to an inappropriate location. Ongoing experiments aim to reveal the mechanisms by which congruent distractors reduce detection accuracy during real-world visual search.

63.409 Neural coding of location, facing direction, and views during spatial imagery Lindsay Morgan[1](lmo@mail.med.upenn.edu), Russell Epstein[1]; [1]Center for Cognitive Neuroscience, University of Pennsylvania

A key aspect of navigation is the ability to imagine the spatial relationships between real-world locations from different points of view. To understand the neural codes that underlie this ability, we scanned University of Pennsylvania students with fMRI while they performed a judgment of relative direction task that required them to make decisions about the locations of buildings on campus. On each 6s-trial, subjects were presented with the names of 3 buildings and were instructed to imagine that they were standing at the first building and facing the second building. They then indicated via button press whether the third building was located to their left or right given their imagined location and facing direction (i.e., their imagined view; e.g., Van Pelt Library facing East). There were 4 possible starting locations (i.e., buildings) and four possible imagined facing directions (North, South, East, or West). Multi-voxel pattern analysis (MVPA) was used to identify brain regions that code: (1) the imagined starting location, (2) the imagined facing direction, and (3) the imagined view. Preliminary results suggest that activity patterns in scene-selective parahippocampal place area (PPA) and retrosplenial complex (RSC) could distinguish between specific views during this spatial imagery task, even though no scene image was shown. In addition, RSC activity patterns distinguish between locations independent of facing direction and facing directions independent of location. These results show that PPA and RSC distinguish between specific scenes (i.e., views) during spatial imagery, and they further suggest that RSC may support allocentric spatial codes that allow one to flexibly recreate these scenes based on long-term spatial knowledge.

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63.410 Processing images in a masked BE paradigm: Does emotion matter? Aisha P Siddiqui[1](aps23@uga.edu), Benjamin McDunn[1], James M. Brown[1]; [1]Department of Psychology, University of Georgia

Boundary extension (BE) is a ubiquitous phenomenon in which people misremember an image as having more information than was previously displayed, so much so that boundary extension even occurs with abstract images on a random dot background (VSS, Siddiqui et al. 2012, 2011). Intraub and Dickinson (2008) have shown that BE can occur when images are visible for as little as 250 ms and followed by a pattern mask. In their study, the pattern mask included a happy face in the center of it, serving as an orienting stimulus. Research on emotional processing suggests emotional stimuli are processed more quickly by the visual system (Globisch, Hamm, Esteves, & Ohman, 2003). The current study tested whether BE would be found using abstract images in a similar masking paradigm and also to determine whether the presentation of a happy face concurrent with the mask facilitated processing of the scene. Encoding time was always 250 ms per image. In separate experiments a 46 ms and a 250 ms pattern mask followed each image before memory was tested. The presence, or absence, of an emotional or neutral orienting stimulus with the mask was compared for the two mask durations. The results showed equivalent BE for the conditions with a happy face, neutral face, or a neutral object at each mask duration. Only at the 46 ms duration was there any indication of reduced BE when there was no orienting stimulus in the mask. If we view BE as an error in processing, our results indicate that during the mask interval with an orienting stimulus, or without an orienting stimulus at a long duration, processing is disrupted leading to BE. However, for a short duration mask without an orienting stimulus processing is disrupted less leading to reduced BE.

63.411 Taking boundary extension to the extreme Ralph Hale[1](rusty7@uga.edu), James Brown[1], Benjamin McDunn[1], Aisha Siddiqui[1]; [1]University of Georgia

A recent model of boundary extension (BE) suggests a number of factors contribute to why people seemingly always remember seeing more of a studied view than was physically present (Intraub, 2011). According to the model we interact with the world from an egocentric frame of reference which leads us to expect that most images we encounter continue beyond their boundaries. Our strategy is to alter cues about the spatial expanse of the scene to see if BE can be reduced/eliminated. Previously we showed BE is still found even when semantic information about objects and scenes was removed by using abstract shapes on random dot backgrounds (VSS, Siddiqui et al. 2012, 2011). These same abstract stimuli were used here with extremal edges introduced at the image boundaries. Extremal edges are the horizons of self-occlusion on smooth convex surfaces and are a powerful cue to depth and figure-ground organization (Palmer & Ghose, 2008). BE was hypothesized to be reduced for images with extremal edges at their boundaries because the edges indicate the images end there. Two size change conditions (16% & 40%) and two viewing conditions (extremal edges present or not) were tested. Forty images were shown to participants for 15 seconds each. Half the images were close-up and half wide-angle versions. After study the forty images were shown again, half at the same view angle and half at the opposite while subjects rated their perceived size. Without extremal edges normal BE was found for the 16% size change condition while there was reduced BE in the 40% condition. With extremal edges BE was reduced for the 16% and eliminated for the 40% condition. Extremal edges provided such a strong cue about the shape/extent of our images there was little reason to expect them to extend beyond their borders.

63.412 Are Neuronal Representations of Fearful Scenes in the Ventral Visual Pathway Size-invariant? Zhengang Lu[1](Zhengang.Lu@dartmouth.edu), Bingbing Guo[1, 2], Ming Meng[1]; [1]Department of Psychological and Brain Sciences, Dartmouth College, [2]College of Bioengineering, Chongqing University, China

Visual processing of fearful scenes provides important cues for human to avoid potential dangers. Using functional Magnetic Resonance Imaging (fMRI), we demonstrated that brain activation in fusiform gyrus (FG) and lateral occipital complex (LOC) correlates with the levels of fearfulness of the scenes (Guo et al., 2012, SFN). However, if this activity represents affective perception of the fearful scenes, it should be invariant to manipulations of low-level stimulus features as long as the manipulation would not alter perceived fearfulness of the scenes. In a factorial design we used fMRI to measure brain activation corresponding to participants observing natural scene pictures with 5 levels of fearfulness × 2 image sizes (small: 200×200 pixels, large: 600×600 pixels). Participants viewed each fearful scene for 2s in a random order and were asked to judge the scene presented was scary or not. By using intact fearful scenes versus scrambled scenes, regions of interests (ROIs) were functionally localized in FG and LOC in each participant with separate scan runs and different stimuli set that was not used in the main experimental runs. Consistent with previous findings, a GLM analysis indicated that there is a linear relationship between brain activation in LOC and FG with the levels of fearfulness. More interestingly, large fearful scenes led to greater MR activity in both LOC and FG than small fearful scenes. Apparently, low-level visual features, such as image size, would actually influence the representations of fearful scenes in LOC and FG. These results may question the thought of functional roles of these brain regions.

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63.413 Spatial and identity associative processing in scene selective cortex 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 are rich visual stimuli depicting places containing both spatial and identity associations. As such, associative processing should be fundamental to scene understanding. To test this hypothesis, we examined novel contextual associative processing in relation to scene processing using fMRI. Scene processing engages a network of brain regions: the parahippocampal cortex (PHC), the retrosplenial complex (RSC), and the transverse occipital sulcus. To the extent that associative processing is fundamental to scene processing, we expected: 1) differential BOLD activity within these regions related to associations; 2) a correlation between this activity and associative learning, reflecting a relationship between associative processing and brain function; and 3) the pattern of BOLD signal related to associative processing would be similar to the pattern related to scene categorical processing, suggesting associations are inherent to scene representation. Novel spatial and identity associations between meaningless novel shapes were taught to participants over a 30-minute training period. Afterwards, fMRI was used while participants viewed the trained associative shapes, scenes, and objects. ROI analyses in the PHC and RSC found significantly more activity for associative shapes compared with non-associative shapes. This differential activity correlated with learning, supporting our association hypothesis. However, these regions showed different patterns of correlation revealing complimentary roles: results from the PHC suggest a process that separates spatial and identity associations; in contrast, results from the RSC suggest a process of combining spatial and identity components into a holistic representation. Moreover, the pattern of activity coding for associations also coded for scene categories (hallways, roads, and intersections) in that identity associative activity discriminated semantically different scenes, whereas spatial associative activity discriminated scenes differing in spatial configuration. Results demonstrate that associative processing in different domains may be reflected in the complimentary information processing roles of PHC and RSC. This elucidates psychological and neural mechanisms underlying scene understanding.

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63.414 Mental representations of layout prime reaching in 3D real world scenes Carmela Gottesman[1](cvgottesman@sc.edu); [1]University of South Carolina, Salkehatchie

Previous research has shown that priming the spatial layout of a scene facilitates distance judgments in pictures. This facilitation is thought to result from the activation of mental representations that include information about the layout of the scene (the location and orientation of surfaces and objects). Supposedly such mechanisms have evolved to aid us in interacting with real world environments but the existence of such priming in real 3D scenes has not been tested. This study examines the effect of a picture prime on the speed of reaching for objects in 3D models. Six 3D models were constructed from Lego bricks. The models were encased in wooden boxes so participants couldn't see the model before each trial began. On Each trial, participants viewed either a picture of one of the models or a control (a picture of a Lego brick wall). They were asked to identify which model they were seeing then asked to go to the model and reach for the closest pink brick in the model. The pink bricks were never shown in the prime picture and they were placed in different locations on different trials. As expected, reactions times were faster when primed with a picture of the model than when primed with a control, suggesting that spatial layout representations facilitate reaching in 3D space as well as distance judgments in pictures.

Multisensory processing: Synesthesia, attention, sensory interaction

Wednesday, May 15, 8:30 am - 12:30 pm

Poster Session, Orchid Ballroom

63.415 **Music-Color Associations from Bach to the Blues: Emotional Mediation in Synesthetes and Non-synesthetes**

Kelly Whiteford[1](kellywhiteford@berkeley.edu), Karen Schloss[1], Stephen Palmer[1]; [1]Department of Psychology

When participants are asked to make associations from classical orchestral music to colors, they choose colors that fit the emotional content of the music: e.g., "happy" colors go with "happy" music and "angry" colors with "angry" music (Palmer, Schloss, Xu & Prado-Leon, in review). Such findings support an emotional mediation hypothesis: cross-modal associations between two perceptually distinct domains can be mediated by shared emotional content. Experiment 1 tested whether emotions also mediate music-color associations with a larger sample of 34 diverse musical genres, including classical, blues, salsa, heavy metal, and hiphop. While listening to each selection, participants picked the three most consistent (and the three least consistent) among 37 colors. Later, they also rated the emotional content of each color and each musical selection on 10 bipolar dimensions: appealing-disgusting, calm-agitated, complex-simple, happy-sad, harmonious-disharmonious, loud-quiet, spicy-bland, warm-cool, whimsical-serious, and liked-disliked. Consistent with emotional mediation, participants reliably matched colors with music having similar emotional content for 9 of the 10 dimensions, with correlations ranging from .91 for calm-agitated to .53 for appealing-disgusting. Preference (liked-disliked) was the only dimension that was unrelated to color choices. Experiment 2 tested whether emotion also mediates the colors experienced by synesthetes, who were instructed to pick the three colors that were most (and least) similar to the colors they experienced while listening to a subset of 18 of the same 34 musical selections. Shared emotional content also influences the relation between the colors experienced to music for synesthetes (e.g., r=.64 for happy-sad). However, these correlations were systematically lower than those for non-synesthetes choosing best/worst color associations (.79 for happy-sad) and also lower than for synesthetes choosing colors that best fit the emotional content of the music (.84 for happy-sad). These and other differences suggest that music-color synesthesia is influenced by both emotion and other sensory-perceptual factors.

63.416 **Context-dependent suppression of color information in grapheme-color synesthesia**

Michiko Asano[1,2](asano@sfc.keio.ac.jp), Manabu Shimizu[3], Kazuhiko Yokosawa[4]; [1]Faculty of Environment and Information Studies, Keio University, Japan, [2]Research Fellow of the Japan Society for the Promotion of Science, [3]Department of Psychology, Faculty of Letters, The University of Tokyo, Japan, [4]Department of Psychology, Graduate School of Humanities and Sociology, The University of Tokyo, Japan

In grapheme-color synesthesia, a visual letter or digit induces a specific color sensation. This implies that grapheme-color synesthetes should experience color inconsistency each time they see graphemes (i.e., graphemes seldom appear in their own synesthetic colors). However, rather than automatically activating a specific color at these times, it is possible that synesthetes excel in suppressing certain synesthetic sensations or at least they can allocate less attention to these colors in particular contexts. This study investigates the ability of suppressing synesthetic sensation in six grapheme-color synesthetes using a visual search paradigm. The task required a search for a target digit ('2' or '5', displayed in a digital font) among distractor digits ('5' or '2', respectively). Both target and distractor digits were displayed in white against either a black or colored background. Results revealed that the digit search slope was statistically significantly (or marginally significantly) shallower (i.e., a more efficient search) when the background color was consistent with the synesthete's own synesthetic color for the distractor digits than when the color of the background was consistent with the synesthetic color for the target digits or when the background color was black. This suggests that items which elicit synesthetic colors consistent with irrelevant background colors were allocated less attention. Search efficiency of synesthetes in the black background condition did not differ from that of age- and gender- matched non-synesthetes, indicating that synesthetic colors for items were not activated pre-attentively and did not facilitate visual search in synesthetes. Collectively, results suggest that synesthetic colors are not pre-attentively activated. Instead, it appears that in a given task grapheme-color synesthetes can allocate less attention so that certain graphemes presented in a given color can be ignored.

Acknowledgement: Grant-in-Aid for Scientific Research from JSPS

63.417 **Music-Color Associations to Classical Music in Synesthetes and Non-synesthetes: The Surprising Role of Emotion**

Stephen Palmer[1](palmer@cogsci.berkeley.edu), Karen Schloss[1], Kelly Whiteford[1]; [1]Psychology Department, U. C. Berkeley

Cross-modal music-to-color associations were investigated in non-synesthetes and music-color synesthetes using 18 selections of orchestral music by Bach, Mozart, and Brahms. Six brief selections were chosen by each composer that varied in tempo (slow/medium/fast) and mode (major/minor). Non-synesthetes chose the 3 colors (from 37) that "went best/worst" with each selection. Synesthetes chose the 3 colors (from the same 37) that were most/least similar to the colors they experienced while listening to the same music. Non-synesthetes showed systematic patterns of cross-modal associations between musical features (tempo and mode) and the four dimensions of color appearance: high/low saturation, light/dark, blue/yellow, and red/green (Palmer, Schloss, Xu, & Prado-León, PNAS, under review). For example, faster music in the major mode was strongly associated with more saturated, lighter, yellower colors, whereas slower music in the minor mode was associated with less saturated (grayer), darker, bluer colors. Timbre-color synesthetes, whose sound-to-color associations are generally thought to be driven by low-level acoustic properties (as opposed to high-level musical ones), showed unexpectedly similar patterns in the colors they experienced while listening to the same selections of music. Both synesthetes and non-synesthetes showed clear evidence of emotional mediation, as indicated by reliable correlations between emotional ratings of the music and corresponding ratings of the colors they experienced/associated with the same music: e.g., the happiness/sadness of the music was correlated .91 with the happiness/sadness of the colors experienced by synesthetes and .95 with the happiness/sadness of the colors associated by non-synesthetes. Similar parallels were evident for the strength/weakness of the music and the strength/weakness of the colors experienced/associated with them (.61 for synesthetes; .96 for non-synesthetes), but not for angriness/calmness, for which non-synesthetes showed similarly high correlations (.89), but synesthetes did not (.33). Some emotions thus play a surprisingly powerful role in the colors experienced by timbre-color synesthetes.

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63.418 **Traits of grapheme-color synesthesia in non-synesthetes**

Jun-ichi Nagai[1](nagai@u-sacred-heart.ac.jp), Kazuhiko Yokosawa[2], Michiko Asano[3,4]; [1]Department of Psychology, University of the Sacred Heart, Tokyo, Japan, [2]Department of Psychology, Graduate School of Humanities and Sociology, The University of Tokyo, Japan, [3]Faculty of Environment and Information Studies, Keio University, Japan, [4]Research Fellow of the Japan Society for the Promotion of Science

Recent research suggests that synesthetes and non-synesthetes lie on a continuum. Grapheme-color synesthetes and non-synesthetes showed comparable regularities in their associations of graphemes with colors (Yokosawa, Nagai, & Asano, 2011, Psychonomics). This study explored how traits of grapheme-color synesthesia emerge in non-synesthetes. Using a questionnaire methodology, 199 young females were asked to choose the most suitable color for each of 40 graphemes (ten from each of four categories: Arabic and Kanji numerals, and Kana and alphabetical vowels) from 11 basic color terms. The same test was repeated twice with a three-week interval. Participants' scores on the consistency of color choices across the two sessions were distributed unimodally with a wide range. A mean split divided participants into high- and low- synesthetic groups. We then compared regularities in grapheme-color association across the two groups. The high-synesthetic group produced a wider variety of significant grapheme-color associations, but considerable similarities were found between the two groups. Correlational analyses of the significant associations showed that both groups tended to associate more frequent graphemes with more distinctive colors, consistent with previous findings on synesthetes' choices. In addition, grapheme ordering and color typicality were correlated. Remarkably, these trends were generally stronger in the low-synesthetic group; they tended to decrease or disappear in the high-synesthetic group. These findings suggest that people with higher synesthetic traits are less dependent on common regularities that produce coarse (i.e., many to many) correlation-based associations; instead, they depend more on fine one-to-one regularities, which may lead to their greater variety of grapheme-color associations with higher consistency over time.

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See page 3 for Abstract Numbering System

63.419 Music-Color Associations to Simple Melodies in Synesthetes and Non-synesthetes Thomas Langlois[1](thomas.langlois@berkeley.edu), Karen Schloss[1], Stephen Palmer[1]; [1]University of California, Berkeley

Previous research on cross-modal music-to-color associations for classical orchestral music revealed systematic mappings in non-synesthetes (Palmer, Schloss, Xu, & Prado-León, under review). There was also strong evidence that emotion mediates these associations, (e.g., happy colors went with happy music). We investigated whether timbre-color synesthetes have similar cross-modal associations between dimensions of music and color for simple, single-line melodies by Mozart, and whether emotion mediates these associations. Synesthetes picked the three colors (from 37) that were most similar (and later least similar) to their synesthetic color experiences while listening to 32 single-line melodies that varied in tonality (major/minor), tempo (slow/fast), note-density (sparse/dense), register (high/low), and timbre (piano/cello). Non-synesthetes picked the three colors (from the same 37) that "went best" (or "went worst") with the same 32 melodies. Like non-synesthetes's music-color associations, synesthetes experienced lighter, yellower, and more saturated colors when listening to melodies in the major mode, and darker, bluer, and less saturated colors when listening to melodies in the minor mode. Synesthetes also experienced redder colors when listening to melodies played on the cello, and bluer colors when listening to melodies played on the piano. Both groups also rated each melody and color along six emotional dimensions (happy/sad, angry/not-angry, agitated/calm, active/passive, strong/weak, and harmonious/disharmonious). Synesthetes' cross-modal associations were mediated by emotion to some degree, because some correlations between corresponding emotional ratings of the music and the colors they experienced were reliable (e.g., .58 for happy/sad). However, they were substantially lower than analogous correlations for non-synesthetes (e.g., .92 for happy/sad) and for the same synesthetes' explicit judgments of the colors that were most/least emotionally compatible with the music (e.g., .81 for happy/sad). Although emotion (particularly happy-sad) plays some role in determining the color experiences synesthetes have while listening to simple melodies, other sensory-perceptual features related to timbre are also important.

63.420 Blindsight: enhanced visual puzzle-solving and memory in synesthesia Elizabeth Seckel[1](eseckel@ucsd.edu), V.S. Ramachandran[1]; [1]UCSD Psychology Department

EA experienced colors when she saw printed letters of the alphabet and numbers. We used three different kinds of puzzle pictures that contained hidden letters which required 30 seconds or more for normal people to identify. EA recognized them three times faster. She said that the colors were evoked prior to conscious letter recognition; clueing her as to what the letters were. She also saw mirror reversed letters the same colors as non-reversed which enabled her to read mirror-reversed text at thrice the normal speed. Thus in some synesthetes colors are evoked preconsciously early in sensory processing. These results remind us of 'blindsight' seen in patients with blindness caused by lesions confined to V1 (WeizKrantz 1986). Analogously, we suggest that in EA the graphemes are processed unconsciously up to the fusiform and cross - activate color cells in V4 before the information is transmitted higher up where the color is utilized to infer the grapheme. We had previously noted (Ramachandran and Brang, 2009) that some lower (projector) synesthetes are better at other unrelated visual tasks such as visual eidetic memory (e.g. finding Waldo even after the picture is briefly shown and removed) and suggested that this - along with their other creative skills - might result from a more widely expressed 'cross connectivity' gene, especially in the visual domain. If so, the possibility exists that EA's skill in tasks is a manifestation of a more general facility with visual puzzles (which would be even more interesting if true!) But her subjective remarks, "I see the colors before I see the shapes" strongly support the blind-sight interpretation. The two hypotheses are not mutually exclusive, of course, and we are currently disentangling them using Shepard's mental rotation and other visual puzzles.

63.421 Capture of positive afterimages by the other senses: Extension of the body schema? Brian Stone[1](brianwstone@gmail.com), Jessica Tinker[1]; [1]Psychology, University of Georgia

Previous research utilizing the Rubber Hand Illusion has demonstrated that external objects can be incorporated into the body schema, but only under restricted conditions, such as when using realistic-looking prosthetic limbs in realistic postures. However, some have argued for a much more permissive view of body schema integration using a related multi-sensory interaction effect within an induced afterimage paradigm. In this paradigm, the participant sits in total darkness and then a bright flash briefly illuminates the scene, causing a vivid afterimage of whatever the participant was looking at. If the afterimage is of a body part, then subsequently moving that body part causes the afterimage of the moved part to fade, due to the conflict between proprioceptive feedback (of movement) and illusory visual feedback (a static afterimage). A recent study found that an object held in the hand and then moved or dropped caused the afterimage of the object – not just the body part holding it – to also fade. The authors argued that this represents a rapid assimilation of external objects into the body schema. The present study replicates and extends these results but tests an alternate account that does not rely on body schema extension. Rather, we argue that fading of the afterimage is due to non-visual sensory feedback updating the brain's representation of an external object's spatial position, and – as with the bodily afterimage effect – the multi-sensory conflict leads to over-writing of the illusory visual information, causing the afterimage to fade (i.e. non-visual capture). We found that auditory and somatosensory feedback of object movement were sufficient to evoke the afterimage fading effect, and our data do not fit parsimoniously with a 'body schema extension' account, but are consistent with a 'sensory feedback' account.

63.422 Components of Attention in Synesthesia Thomas Alrik Sørensen[1,3](thomasalrik@gmail.com), Maria Nordfang[2], Michael Nygaard Pedersen[3], Morten Storm Overgaard[1,3], Árni Gunnar Ásgeirsson[2]; [1]Department of Communication and Psychology, Aalborg University, [2]Department of Psychology, University of Copenhagen, [3]Cognitive Neuroscience Research Unit, Aarhus University

One of the most common forms of synesthesia is between colors and graphemes (Colizoli, Murre, & Rouw, 2012). Numerous studies have investigated different aspects of attention and synesthesia, e.g. effects of Stroop-like interference by colors that are incongruent with the synesthetic experience. Here we attempt to isolate how specific components of attention are affected by grapheme-color synesthesia. Eight carefully screened healthy participants with synesthesia reported the letters in briefly presented, post-masked arrays of letters and digits. On half the trials, the letters and digits were presented in colors congruent with the synesthetic experience. On the other half of the trials, the letters and digits were presented in colors that were incongruent with the synesthetic experience. Components of attention were estimated separately for congruent and incongruent trials by fitting the data to a mathematical model based on A Theory of Visual Attention (Bundesen, 1990). It has previously been demonstrated that color experiences in observers with synesthesia are very stable over time, and that the color experience seems to be an integrate part of the processing of letters, in for example grapheme-color synesthesia (Mattingley, 2009). Results from the present experiment show that synesthesia affects both speed of processing (C) and the number of objects that can be retained in visual short-term memory (K). Participants were faster at encoding characters that were colored congruently with their synesthesia. In addition, the capacity of the visual short-term memory increased slightly in the congruent compared to the incongruent condition. Interestingly, congruent trials compared to incongruent trials did not seem to afford benefits to attentional selectivity (α), nor did they affect the threshold for visual perception ($t0$). The results, therefore, indicate that synesthesia relates to a specific subset of attentional components.

63.423 Visual search based on synesthetic color without overt attention Eun-hye Shin[1](10638311@hanmail.net), Chai-Youn Kim[1]; [1]Department of Psychology, Korea University

Color-graphemic synesthetes experience "color" when viewing achromatic alphanumeric characters. Previous studies have suggested that synesthetic colors behave like real colors in tasks where color is important. For example, some studies reported faster or more accurate performance by synesthetes searching for an achromatic inducing target among other achromatic distractors relative to normal controls (Palmeri et al., 2002; Ramachandran & Hubbard, 2001; Smilek et al., 2001). However, other studies found that synesthetes enjoy no advantage over control subjects (Edquist et al., 2006; Gheri et al., 2008). In the present study, we employed a visual search paradigm while varying viewing conditions in consideration of the angular size of the search array as well as the angular subtense of each item. Three color-graphemic synesthetes (all associators) and matched controls participated in this study. Stimuli (e.g., 2 among 5s) of resolvable sizes were presented in array of three concentric circles (near: 1.99°, intermediate: 3.52°, and far: 6.49°). Conditions included set size (small: 12, medium: 18, and large: 24), color (real, synesthetic), and viewing (free, center-fixed). Observers made a speeded judgment detecting the target presence while their eye movement was monitored. Free Viewing: In the real color condition, synesthetes and controls didn't show any difference in search performance. However in the synesthetic color condition, synesthetes were faster than controls searching the target with no loss of accuracy, supporting the perceptual reality of synesthetic color. Fixed Viewing: Overall, synesthetes were faster than controls searching the target. However synesthetes were not faster and less accurate than controls when the achromatic inducing target was located near fixation. The present results imply that synesthetes are better finding a "colored" target even without overt attention. However, performance enhancement by synesthetic color is evident when visual acuity falls off so that search becomes difficult solely based on the shape information.

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63.424 **Visuohaptic Crossmodal Matching: A Developmental fMRI Study** R. Joanne Jao[1](rjjao@indiana.edu), Thomas James[1], Karin James[1]; [1]Indiana University

Research on the development of crossmodal (intersensory) perception of visual and haptic inputs suggests that communication within sensory systems develops earlier than communication across sensory systems. These behavioral changes reflect the development of neural substrates, but little is known about the neural mechanisms that underlie the developmental progression of haptic perception or visuohaptic interactions. To address this gap in knowledge, BOLD fMRI was measured during intramodal (visual-to-visual, haptic-to-haptic) and crossmodal (visual-to-haptic, haptic-to-visual) delayed match-to-sample recognition tasks with novel objects in children aged 7-8.5 years and in young adults. Tasks were further divided into encoding (sample) and matching (test) phases. During matching, adults and children demonstrated similar results. Whole-brain comparisons of intramodal and crossmodal object matching to rest revealed the network of known visuohaptic multisensory substrates, including the lateral occipital complex (LOC) and intraparietal sulcus (IPS). Comparisons of crossmodal versus intramodal conditions (i.e., (HV>VV) ∩ (HV>HH), (VH>VV) ∩ (VH>HH)) produced significant clusters in the same regions, and further, indicated specific effects of crossmodal directionality. In particular, haptic-to-visual matching tasks activated ventral regions (LOC) in both groups, while visual-to-haptic matching tasks activated dorsal regions (IPS) in adults only. Moreover, in the regions of interest as defined by contrasts with rest, crossmodal matching showed greater activation than intramodal matching. Specifically, results revealed this pattern in LOC during haptic-to-visual matching and in IPS during visual-to-haptic matching. Overall, children were highly similar to adults with the exception of some developmental differences in IPS. These results converge with existing findings on the multisensory nature of the IPS and LOC in adults, and extend our knowledge of the development of haptic perception and crossmodal integration. Critically, the results highlight the dominance of crossmodal over intramodal processing, as well as the different influences of test modality on the dorsal (IPS) and ventral (LOC) sites for visuohaptic object processing.

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63.425 **No visual-proprioceptive re-weighting after removal of vision** Brendan Cameron[1], Joan López-Moliner[1]; [1]Departament de Psicologia Basica, Universitat de Barcelona

When the target of a reach is on one's body (e.g., a bug to swat), visual and proprioceptive information about both the effector and the target can be used to plan the movement. If vision is removed, proprioceptive information should receive increased weighting to compensate for the decaying visual representation. We investigated whether the rate of re-weighting was equivalent for the effector and the target. In our experiment participants received visual information (projected dots representing the unseen left and right index fingers) that was shifted (near/far) with respect to the fingers' veridical locations. Zero, two, or five seconds after the dots were extinguished, participants rapidly aimed with a stylus to their left index finger, which was located directly under the reaching surface. The visual manipulation influenced reaching, but the direction of the effect differed across participants: some participants aimed high (low) when the visual information about the hand and target was below (above) the veridical positions, which suggests preferential coding of visual information about the effector, while some participants aimed low (high) when the visual information was below (above) the veridical positions, which suggests preferential coding of visual information about the target. More surprising was the absence of any effect of the delay manipulation; the effect of the visual manipulation was constant across all 3 delays for all participants. Moreover, we saw no increase in variable error as delay increased. These results suggest that a reliable visual position estimate persisted for at least 5 seconds. In the absence of intervening hand and/or eye movements (in our study participants maintained fixation throughout the trial and their hands were stationary until the onset of the reach), visual memory for hand location may be as robust as real-time proprioception.

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63.426 **Caught off-balance by the motion aftereffect** Vivian Holten[1](v.holten@uu.nl), Stella F. Donker[1], Maarten J. van der Smagt[1], Frans A.J. Verstraten[1,2]; [1]Division of Experimental Psychology, Helmholtz Institute, Utrecht University, The Netherlands, [2]School of Psychology, The University of Sydney, Australia

Visual stimuli simulating self-motion through the environment can induce potent postural adjustments in observers. This suggests a rather direct, stimulus driven, mechanism subserving these visuo-vestibular interactions. Here we examine whether visual-motion induced sway is the result of predominantly external stimulation, or whether it can be induced by an (illusory) internal representation of visual motion, as apparent in the motion-aftereffect (MAE) as well. We presented a random-pixel-array (RPA) (pixel size ~0.08 degrees, viewed through either a 8x8 degree or 87x56 degree aperture) translating at ~3 deg/s leftwards or rightwards during adaptation. A static version of the RPA, or a dynamic version, where each pixel was refreshed every 16.7 ms, were used as test pattern. Observers, standing on a force plate in a completely dark room in front of the projection screen, received an initial 40s adaptation, followed by 20s top-up adaptation epochs, that were interleaved by 14s test pattern epochs (either static or dynamic, presented in pseudo-random order). Each type of test pattern was presented 20 times per condition. Observers had to press a button to report when the MAE had dissipated (if <14s). MAE duration was longer for static than dynamic test patterns. Using the large aperture we observed more postural sway for a static than a dynamic test pattern, and the amount of sway appeared related to the strength (i.e. duration) of the illusory motion. For the small RPA, no difference in postural sway between the two test patterns was observed. The results demonstrate that illusory motion caused by a MAE can induce postural sway of which the amount depends on the test pattern and stimulus size. This suggests that visuo-vestibular interactions observed in visual-motion induced sway can at least be modulated by the conscious visual experience.

63.427 **Acute Disturbances of Vision during Walking and Turning** Nicholas Murray[1](ngmurray@utep.edu), Marlina Ponce de Leon[2], V.N. Pradeep Ambati[1], Fabricio Saucedo[2], Evan Kennedy[2], Rebecca Reed-Jones[2]; [1]Interdisciplinary Health Sciences PhD Program, College of Health Sciences, The University of Texas at El Paso, [2]Department of Kinesiology, College of Health Sciences, The University of Texas at El Paso

During a turn, the body follows a specific motor synergy: the eyes move in the direction of travel followed by the head, trunk, and pelvis. While a number of hypotheses exist on the role of visual information during a walking turn, no one has examined turning behavior in the presence of acute visual deficits of the peripheral and central visual fields. The purpose of the current research was to examine how body segment coordination alters in response to an acute loss of peripheral or central vision during a 90-degree walking turn. Three-dimensional kinematic data of the head, trunk, and pelvis segments were collected on fifteen healthy young adults while they performed a 90-degree walking turn (120 Hz; Vicon, MX). Each participant completed 10 turns in each of three visual conditions created through the use of vision altering glasses: Non-impaired (Control), Peripheral Loss, and Central Loss. Analysis of segment rotations revealed significant differences in head, trunk, and pelvis coordination between the Non-Impaired, Peripheral, and Central Loss conditions ($p < 0.001$). In the Non-Impaired condition, the head moved significantly earlier (520 ms) than the thorax (760 ms) and Pelvis (851ms) respectively ($p < 0.05$). Similarly, during Central Loss, head rotation significantly led trunk rotation ($p = 0.043$; head 752 ms and trunk 892 ms respectively). However, during Peripheral Loss the head did not lead the trunk significantly, rather significant timing differences were only observed between the head and the pelvis ($p = 0.024$; head 492 ms and pelvis 750 ms). Therefore, Peripheral Loss was the only visual condition where the head did not precede the trunk, suggesting disruption of the turning motor synergy. These results indicate that visual information derived from the Peripheral field contributes critical information to the Central Nervous System for turning control.

63.428 **Is there a 'retinotopic' representation of echo locations in the calcarine cortex of the blind brain?** Jennifer L. Milne[1,2](jmilne4@gmail.com), Melvyn A. Goodale[1,2,3], Lore Thaler[4]; [1]The Brain and Mind Institute, The University of Western Ontario, London, Canada, [2]Neuroscience Program, The University of Western Ontario, London, Canada, [3]Department of Psychology, The University of Western Ontario, London, Canada, [4]Department of Psychology, Durham University, Durham, United Kingdom

We have shown previously that activity in calcarine cortex of an early blind echolocation expert is greater for mouth-click echoes reflected from objects located in contralateral space. Here, we used fMRI to investigate in more detail whether or not the mapping of echoes in the calcarine cortex of an early blind echolocation expert resembles retinotopic mapping in the sighted brain. We also investigated the mapping of sound sources. An early blind expert echolocator listened to binaural recordings of echolocation and source sounds in the fMRI scanner. The recordings were made earlier as the echolocator made clicks in the presence of a sound reflecting surface (or simply listened to a sound emitting loudspeaker) located at azimuth angles from -60°, -20°, 0°, +20°, to +60°. In addition, at -20° and +20° azimuth, recordings were made separately at 0°, -20° and +20° elevation. For each location in echo and source conditions, the participant had pressed a response key with a separate finger. For echolocation, we were able to map -20° azimuth in medial right calcarine, +20° azimuth in medial left calcarine, and 0° azimuth towards the apex of the occipital pole. For source hearing, we were able to map only -60° azimuth in medial right calcarine, anterior to the -20° azimuth echo representation. We were unable to map elevation for either echoes or sources. We were able to confirm the validity of our analysis by mapping the motor representation of the fingers used to press the response keys. In their entirety, the data are consistent with the idea that there is a representation of azimuth of echo locations in calcarine cortex that resembles the representation of azimuth of visual locations in retinotopic coordinates. The data suggest that this mapping is more pronounced for echolocation than source hearing.

Eye movements: Microsaccades

Wednesday, May 15, 8:30 am - 12:30 pm

Poster Session, Orchid Ballroom

63.429 **Microsaccades correct fixation errors due to blinks** Francisco Costela[1,2](francisco.costela@gmail.com), Jorge Otero-Millan[1,3], Michael McCamy[1], Stephen Macknik[1], Xoana Troncoso[1,4], Susana Martinez-Conde[1]; [1]Department of Neurobiology, Barrow Neurological Institute, [2]Program of Neuroscience, Arizona State University, [3]Department of Signal Theory and Communications, University of Vigo, [4]Division of Biology, California Institute of Technology

Our eyes are continuously moving. Even when we attempt to fix our gaze, the position of our eyes is not stable. Furthermore, our eyes move every time we blink. No study to date has paid attention to the change in eye position caused by blinks and their interaction with other fixational eye movements (microsaccades and drifts). We used eye movement data recorded during attempted fixation from seven awake rhesus macaques that were implanted with a scleral search coil in one eye. We found that the eye position at the end of a blink does not correspond with the position before its beginning (typical error of 0.8 degrees in macaques). Microsaccades were typically triggered in the 400 ms following a blink and their direction and magnitude matched the error of the blink better than chance. 61% of all microsaccades that occurred after a blink decreased the error. Large errors (> 0.2 deg) were more effectively corrected than smaller ones. Drifts also showed some level of correction but less than that of microsaccades. Our results show that blinks contribute to the instability of gaze during fixation and that microsaccades typically correct for the error introduced by blinks more than drifts. These findings provide critical new insights about eye position control during fixation.

63.430 **Space-time dependence of fixational saccades** Claudia Cherici[1](cherici@bu.edu), Michele Rucci[1,2]; [1]Department of Psychology, Boston University, [2]Graduate Program in Neuroscience, Boston University

Recent work has shown that microsaccades precisely relocate gaze in high-acuity tasks (Ko et al, 2010). Fixational saccades, however, also occur when attempting to maintain steady fixation on a single point, with no other visual stimulus present. What is the function of these movements? It has long been debated whether fixational saccades correct for fixation errors (i.e., they are elicited by spatial displacement between the current gaze position and the intended fixation point) or their generation depends instead on temporal factors rather than spatial ones. This controversy has never been solved, primarily because of technical limitations on precisely determining where subjects look. Whereas eye-tracking may enable detection of very small changes in gaze position, the absolute localization of the line of sight is typically affected by an area of uncertainty as large as the fovea itself, a problem in part caused by the occurrence of fixational eye movements during preliminary calibration procedures. To overcome this problem, we developed a gaze-contingent calibration procedure, which effectively improved localization of the line of sight by one order of magnitude over standard methods. Using this improved accuracy, we examined the characteristics of fixational saccades in 6 human observers while they maintained fixation on a small dot. Our results show that the generation of fixational saccades depends both on space and time. Fixational saccades occurred relatively frequently even when the center of gaze was very close to the requested location. However, the rate of fixational saccades increased proportionally with the distance of the current location of gaze from the fixation marker. Unexpectedly, saccades were extremely accurate in correcting for fixation errors, especially on the horizontal axis. Thus fixational saccades primarily serve a corrective function, but they occasionally occur when not needed, as they can only be suppressed for a limited period of time.

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63.431 **Microsaccadic efficacy and contribution to the prevention of visual fading** Michael McCamy[1,2](mike.mccamy@gmail.com), Stephen Macknik[1,3], Susana Martinez-Conde[1]; [1]Department of Neurobiology, Barrow Neurological Institute, Phoenix, [2]School of Mathematical and Statistical Sciences, Arizona State University, Tempe, [3]Department of Neurosurgery, Barrow Neurological Institute, Phoenix

Our eyes move constantly. Even when we try to fixate our gaze, we produce "fixational" eye movements, including microsaccades, drift and tremor. Fixational eye movements are thought to be critical to vision, but no studies have quantified their separate impacts on preventing versus restoring visual loss during fixation. Recently, we showed that microsaccades are the most important eye movement contributor to restoring faded vision during fixation (McCamy et al., 2012). Here we modified our previous method and used it to calculate the microsaccade efficacy and contribution to preventing visual fading. We recorded the eye movements of human observers while they reported, via button press, when foveal and peripheral visual targets faded or intensified perceptually. We defined the contribution of microsaccades (and other eye movements) to preventing visual fading, as the percentage of fading preventions caused by microsaccades (and other eye movements), and the efficacy of microsaccades as the percentage of microsaccades that prevented fading. Our data show that both microsaccades and drift contribute to preventing faded foveal and peripheral vision, but that microsaccades are more effective. Microsaccades prevent both foveal and peripheral fading in an equivalent fashion, and microsaccadic sizes, numbers, and directions are equally effective at preventing fading. These combined results indicate that microsaccades and drift work together to prevent fading, and that drift alone does not prevent fading perpetually, thus microsaccades are necessary. Microsaccades do not occur at all times, however, and so the oculomotor system must achieve a delicate balance between microsaccades and drift to prevent and restore faded vision. REFERENCE: McCamy, M. B., Otero-Millan, J., Macknik, S. L., Yang, Y., Troncoso, X. G., Baer, S. M., Crook, S. M., et al. (2012). Microsaccadic Efficacy and Contribution to Foveal and Peripheral Vision. The Journal of Neuroscience, 32(27), 9194–9204. doi:10.1523/JNEUROSCI.0515-12.2012

63.432 **Suppressive interactions underlying visually evoked miniature saccades** Helena X Wang[1](helena.wang@nyu.edu), Shlomit Yuval-Greenberg[2,3], David J Heeger[1,2]; [1]Center for Neural Science, New York University, [2]Department of Psychology, New York University, [3]Department of Neurobiology, The Hebrew University of Jerusalem

Purpose. To constrain computational models of underlying neural activity by characterizing how saccades during intended fixation depend on the spatial locations and contrasts of pairs of visual stimuli. Methods. Observers were instructed to maintain fixation on a small central marker, while parafoveal and peripheral spots were each flashed briefly (80 ms) and regularly at each of four cardinal locations (above, below, left, or right of fixation). A parafoveal stimulus (0.8° eccentricity) was presented either alone or simultaneously with one of the peripheral stimuli (5° eccentricity). We systematically varied the contrast of the parafoveal stimuli, while holding the contrast of the peripheral stimuli (when present) constant. Eye movements were recorded with a video-based eye tracker (Eyelink 2000, SR Research) to detect miniature saccades (<1°) following each stimulus presentation. Results. A large proportion of miniature saccades were biased toward the parafoveal stimuli ("congruent saccades"). Congruent saccades typically occurred 100-200 ms following stimulus onset. A later increase in overall miniature saccade rate was also evident, as documented in the literature, but it did not exhibit congruency toward the parafoveal stimuli. The rate of congruent saccades increased with parafoveal stimulus contrast and saturated at high contrasts when the parafoveal stimuli were presented alone. Congruent saccade rate was suppressed by the peripheral stimuli. The effect of the peripheral stimuli could best be characterized as subtractive, i.e., leading to a constant decrease in miniature saccade rate at all parafoveal contrasts. Conclusion. We interpret these results in the context of computational models of neural activity in the visuomotor map of the superior colliculus. Visual stimulation near fixation biases the vector mean of activity toward the representation of the stimulus. Distant stimuli interact with nearby stimuli, suppressing activity and reducing the rate of miniature saccades evoked by nearby stimuli.

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63.433 **Accuracy and precision of microscopic saccades** Martina Poletti[1](martinap@bu.edu), Michele Rucci[1-2]; [1]Department of Psychology, Boston University, Boston, Massachusetts 02215, [2]Graduate Program in Neuroscience, Boston University, Boston, Massachusetts 02215

We have recently shown that microsaccades relocate the gaze toward regions of interests in a high visual acuity task (Ko et al., 2010, Nature Neuroscience). This finding raises the question of how precisely humans control these tiny movements. Previous studies investigating this issue could only give a superficial account of the precision and accuracy of microsaccades because of two major technical limitations. First, they could not accurately localize the line of sight in space, because of the inherent uncertainty caused by fixational eye movements during preliminary calibration procedures. Second, they could not compensate for fixational instability as it occurs, and presented saccade targets at fixed positions on the display rather than at fixed retinal locations. To overcome these problems, we developed a gaze-contingent calibration, which effectively reduces uncertainty in localization of the line of sight by one order of magnitude. Second, we compensated for fixational eye movements by placing saccade targets at the desired distance on the retina. Our results show that microsaccades between 7′ and 20′ produce larger angular errors, but smaller amplitude deviations than larger saccades. Microsaccades also tend to be more precise than larger saccades, yielding a smaller dispersion of their landing position. Although less efficient than larger saccades, they reduce the distance between the center of gaze and the saccade target by more than 50%, particularly for microsaccades larger than 14′. These factors are taken into account by the motor system; the probability of eliciting a microsaccade decreases with targets located at eccentricities for which the microsaccade is likely to increase rather than reduce the visual error. These results have important implications for the role of microsaccades in vision: they demonstrate that the oculomotor system controls microsaccades almost at the same level of larger saccades.

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63.434 **An Eye Movement Continuum from Exploration to Fixation** Jorge Otero-Millan[1,2](jom@neuralcorrelate.com), Stephen L Macknik[1,3], Rachel E Langston[1,4], Susana Martinez-Conde[1]; [1]Neurobiology, Barrow Neurological Institute, Phoenix, [2]Signal Theory and Communications, University of Vigo, Vigo, Spain, [3]Neurosurgery, Barrow Neurological Institute, Phoenix, [4]University of Arizona, Tucson

During visual exploration, saccadic eye movements scan the scene for objects of interest. During attempted fixation, the eyes are relatively still but often produce microsaccades. Saccadic rates during exploration are higher than those of microsaccades during fixation, reinforcing the classic view that exploration and fixation are two distinct oculomotor behaviors. An alternative model, heretofore untested, is that fixation and exploration are not dichotomous, but are instead two extremes of a functional continuum. Here, we measured the eye movements of human observers as they either fixed their gaze on a fixation spot, or scanned natural scenes of varying sizes. As scene size diminished, so did saccade rates, until they were continuous with microsaccadic rates during fixation. Other saccadic properties varied as function of image size as well, forming a continuum with microsaccadic parameters during fixation. This saccadic continuum extended to non-restrictive, ecological viewing conditions that allowed all types of saccades and fixation positions. Eye movement simulations moreover showed that a single model of oculomotor behavior can explain the saccadic continuum from exploration to fixation, for images of all sizes. These findings challenge the view that exploration and fixation are dichotomous, suggesting instead that visual fixation is functionally equivalent to visual exploration on a spatially focused scale.

63.435 **Implications of Microscopic Eye Movements for Retinal Encoding** John George[1](jsg@lanl.gov), Jennifer Schei[1], Peter Schultz[2], Garrett Kenyon[1,2]; [1]Los Alamos National Laboratory, [2]New Mexico Consortium

The eye is constantly moving. In addition to voluntary saccades, "fixational" eye movements, drift and tremor on the scale of individual photoreceptors, overlap frequencies of oscillations observed in LGN and cortex. Such eye movements are implicated in the perception of fine spatial detail and other perceptual tasks. We set out to explore mechanisms underling perceptual consequences of microscopic eye movements using computational models, and retinal electrophysiology. We postulate that eye movements temporally modulate the visual response; that precisely timed and spatially coherent neural population activation enhances the detection and learning of visual features, and may encode relationships between features. We employed a model of the outer retina developed by van Hateren, (expanded to a 32x32 array of photoreceptors, with electrical coupling between horizontal cells) coupled to spiking models of the inner retina and primary visual cortex, implemented in our package Petavision. We employed a range of stimuli: illuminated points, noisy Gabor gratings, and still images. Stimulus patterns were randomly displaced. Movement orthogonal to the orientation of a grating blurred structure and reduced contrast encoded by spike rate, ultimately obliterating spatial detail. In contrast, orthogonal movements enhanced reconstructions based on temporal covariance. This effect might enhance detection of extended spatial features encoded by synchronized firing. In electrophysiological studies of isolated retina (tiger salamander), we simulated eye movements by jittering the visual stimulus; responses were recorded with multi-electrode arrays. As predicted, synthetic eye movements elicited a strong periodic response at the jitter frequency from individual cells in the salamander retina. Our models suggest that microscopic eye movements might enhance the representation of features in visual imagery encoded by correlation within a population of neurons. These predictions are testable: by functional optical imaging and electrode array measurements in isolated retina or by psychophysical investigation of the detection of perceptual targets perturbed by microscopic displacements.

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63.436 **Microsaccade latency uncovers stimulus predictability: Faster and longer inhibition for unpredicted stimuli** Yoram Bonneh[1,2](yoram.bonneh@gmail.com), Yael Adini[3], Dov Sagi[2], Misha Tsodyks[2], Moshe Fried[4], Amos Arieli[2]; [1]Department of Human Biology, University of Haifa, Israel, [2]Department of Neurobiology, The Weizmann Inst. of Science, Rehovot, Israel, [3]Vision Research Inst., Kiron, Israel, [4]Goldschleger Eye Research Institute, Tel-Aviv University, Israel

Background: Microsaccades are known to be inhibited in response to perceptual events. We have recently reported (Bonneh et al, VSS 2012) that the latency of the release from inhibition depends systematically on the history of preceding events. Here we explore both the onsets and offsets of this inhibition using various visual and auditory stimuli. Method: During fixation observers viewed and silently counted all items in sequences of 100 randomly ordered stimuli of two types, presented at 1 Hz repetition rate. These included small patches of contrast (high/low), color (red/blue), spatial position (up/down), and audio-visual stimuli (beep/circle). Eye-tracking data were used to compute the average latencies of the first microsaccade (if present) in two time windows: early (0-300 ms) corresponding to the onset of inhibition, and late (e.g. 200-700 ms, varied across conditions) corresponding to inhibition release. Results: In all conditions, repetition (e.g. red after a sequence of reds) delayed the onset of inhibition and shortened the latency of its release, while change (e.g. red after a sequence of blues) shortened the onset of inhibition (as early as 100ms) and increased the latency of its release. The magnitude of these effects changed systematically with the number of preceding items (up to 4-5), 5-10ms per item, with 20ms per item for the total inhibitory duration. We verified the significance of the effects in comparison to a random shuffle (Monte-Carlo method). Conclusion: Microsaccades are inhibited in time intervals that depend on the relation between the current event and the pattern of preceding events. We describe this dependency in terms of a simple quantitative model that computes the likelihood ("prediction") of future events based on the recent past, and assumes faster and longer inhibition for events with higher prediction error. The current measure of implicit perceptual predictions could be applied to non-communicating individuals.

Acknowledgement: The US–Israel Binational Science Foundation (DS)

63.437 **Adaptivity of fixational saccadic eye movements in a visual detection task** Sara Spotorno[1,2](s.spotorno@dundee.ac.uk), Anna Montagnini[1], Laurent Madelein[1,3], Guillaume Masson[1]; [1]Institut de Neuroscience de la Timone, CNRS and Aix-Marseille University, France, [2]School of Psychology, University of Dundee, Scotland UK, [3]Psychology, Ureca - Univ. Lille 3, Villeneuve D'Ascq, France

Recent studies have established that fixational saccades may improve the visual performance in difficult tasks demanding the efficient processing of fine details (Ko, Poletti & Rucci, 2012). On the other hand, Rucci et al. (2007)

suggested that the specific effect of fixational eye movements is to reduce the impact of low-frequency noise, by flattening the spectrum typical of natural visual scenes. We investigated whether fixational saccades can be adaptively modulated in a visual detection task in order to maximize stimulus-related information. In a grating detection task, with a 2-interval forced choice paradigm, we used 3 frequencies and 4 contrast levels. In each trial, in one interval a vertical oriented grating was presented superposed with a pink noise, while in the other interval the noise was presented alone. Eye movements were recorded with an Eyelink 1000 video-based eye tracker. We found that saccade amplitude was largely dependent on noise, and this pattern did not vary significantly with grating frequency or contrast. However, a large proportion of saccades were perpendicular to grating orientation, suggesting that saccade direction is mainly controlled by grating orientation and by strategy of spatial information gathering.

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63.438 **Microsaccades Boost Face Identification** Junpeng Lao[1](junpeng.lao@unifr.ch), Lingnan He[2], Roberto Caldara[1]; [1]Department of Psychology, University of Fribourg , [2]The School of Communication and Design, Sun Yat-Sen University

Human eyes continuously and dynamically feed the retina with distinct visual inputs. Even during gaze stability, the eyes are performing small relocations to prevent for visual fading. Among these fixational eye movements, the fastest and the largest are microsaccades. Microsaccades were asserted as being functionally similar to saccades, scanning visual inputs to gather relevant information for the task at hand. This functional hypothesis remains controversial and has never been yet investigated for the biologically relevant class of faces. This is even more interesting, since Westerners preferentially fixate the eyes and mouth during face identification. Strikingly, Easterners focus more on the central facial region and weather this cultural perceptual bias is coded by microsaccades is unknown. To this aim, we examined the occurrence of microsaccades while Western and Eastern observers were performing a face identification task with their fixation maintained on the center of the screen. Observers first learnt 8 face identities. To investigate microsaccade orientation, we defined 9 equidistant Viewing Positions (VPs) covering the internal facial features. Faces stimuli were presented on a random VP centered with the fixation cross. Western and Eastern observers showed a similar face identification performance and comparable microsaccades patterns. Microsaccade rate followed a typical time course, an early inhibition from 100ms with a burst occurring between 150 to 300ms. The eyes elicited the highest rate of microsaccades in this later time-window. In addition, all the microsaccades occurring on the outward VPs were strongly oriented to horizontally center the face stimulus, with no specific orientation preference in the midline VPs. Crucially, observers identified faces significantly faster if they performed a microsaccade in this time-window. Our data show that microsaccades are boosting face identification performance by centering facial information and speeding response times. Microsaccades are universally tuning visual inputs to optimize face processing and identification.

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63.439 **Perceptual rivalry and the relationship between microsaccades and pupil dilation** Brian Metzger[1,2](bmetzge2@illinois.edu), Diane Beck[1,2], Daniel J. Simons[1,2]; [1]Department of Psychology, University of Illinois Urbana-Champaign, [2]Beckman Institute for Advanced Science and Technology, University of Illinois Urbana-Champaign

Microsaccade rate and changes in pupil size each have been linked to attention (Rolfs, 2009; Gabay et al., 2011) as well as to perceptual alternations in binocular rivalry (Van Dam & Van Ee; Einhaeuser et al., 2008), suggesting a relationship between microsaccade inhibition and pupil dilation. The two measures have been studied independently, though, so it remains unclear if these changes are related. Experiment 1 explored the relationship between the two measures. Microsaccade rate and pupil size were recorded using a video-based eye-tracker as participants viewed orientation-ambiguous figures such as a Necker cube. Increases in pupil size were accompanied by decreases in microsaccade rate while decreases in pupil size were accompanied by increases in microsaccade rate during transitions from one interpretation to the other, confirming that the measures are associated. This covariation either indexes a shared cognitive component such as effort (Valsecchi & Turatto, 2009; Norman & Bobrow, 1975) or a more general association such as an automatic physiological link. To determine whether they co-vary due to a physiological link, Experiment 2 manipulated pupil size by modulating screen luminance and measured changes in microsaccade rates. Although pupil size changed with increases and decreases in luminance, microsaccade rates were not associated with those changes. Consequently, the association between pupillary responses and microsaccades seems to require a shared cognitive component such as attention or cognitive effort.

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63.440 **Microsaccade and drift dynamics reflect mental fatigue during visual search** Leandro L. Di Stasi[1, 2, 3](distasi@ugr.es), Michael B. McCamy[1], Andrés Catena[4], Stephen Macknik[5,1], Jose J. Cañas[2], Susana Martinez-Conde[1]; [1]Department of Neurobiology, Barrow Neurological Institute, Phoenix, [2]Cognitive Ergonomics Group, Faculty of Psychology, University of Granada, Spain, [3]Joint Center University of Granada - Spanish Army Training and Doctrine Command, Spain, [4]Learning, Emotion and Decision Group, Faculty of Psychology, University of Granada, Spain , [5]Department of Neurosurgery, Barrow Neurological Institute, Phoenix

Our eyes are always in motion. Even during periods of relative fixation, we produce so called "fixational eye movements", which include microsaccades, drift, and tremor. Mental fatigue and task difficulty can modulate saccade dynamics, but their effects on fixational microsaccades and drift are unknown. Here we asked human subjects to perform a prolonged and demanding visual search task (a simplified air traffic control task), with two difficulty levels, under both free-viewing and fixation conditions. Saccadic and microsaccadic velocity decreased with time-on-task, whereas drift velocity increased, suggesting that ocular instability increases with mental fatigue. Task difficulty did not affect eye movements, despite increased reaction times, performance errors, and subjective complexity ratings. We propose that variations in eye movement dynamics with time-on-task are consistent with the activation of the brain's sleep centers in correlation with mental fatigue. Covariation of saccadic and microsaccadic eye movements moreover supports the hypothesis of a common generator for microsaccades and saccades. We conclude that changes in fixational and saccadic dynamics indicate mental fatigue reliably during prolonged visual search, independent of task complexity. These findings have implications for the interpretation of current results and the design of future experiments in visual and oculomotor neuroscience.

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63.441 **Cognitive Load Modulates Microsaccade Rate and Pupil Size** Xin Gao[1](gaoxin_xinli@163.com), Chao-yi Li[1,2], Yong-chun Cai[3], Hong-jin Sun[4]; [1]Key Laboratory of Neuroinformation of Ministry of Education, School of Life Science and Technology,University of Electronic Science and Technology of China,Chengdu,China, [2]Shanghai Institutes of Biological Sciences, Chinese Academy of Science,Shanghai,China, [3]Department of Psychology and Behavioral Sciences, Zhejiang University, Hangzhou, China, [4]Department of Psychology, Neuroscience & Behaviour, McMaster University, Canada

Microsaccade (MS) is the largest and fastest component of fixational eye movements. Recently, several behavioral studies have attempted to establish links between microsaccade and various cognitive activities. In this study, we examined the relationship between cognitive load and MS rate. While studies linking MS rate with cognitive activities typically employed visual tasks, in this study, we examined MS rate in a mental arithmetic task, where, after initial visual presentation of the calculation required, visual processing was no longer required during the actual calculation. Cognitive load was manipulated by varying number of digits involved in the calculation. We used the time it took to finish the task (response time, RT) as the indicator for cognitive load. We also recorded pupil size which has been linked to cognitive load. After a display of a fixation spot, two numbers were presented sequentially on the center of the screen. Before and after the display of these two numbers, an operational sign ("+"for addition; "-"for subtraction) was also displayed on the center of the screen. Participants made a verbal response as soon as they finished the calculation. We found that MS rates immediately following calculation increased to and maintained for a period of time at a level about twice of that during calculation. During calculation, MS rates were higher for trials with longer RTs (linear regression $r = 0.57$, $p=0.016$), while after calculation MS rate were much less affected by RTs. Moreover, during calculation, pupil size increased. Following calculation, pupil size continued to increase for a short period of time then decreased. The peak pupil sizes were higher for longer RTs (linear regression r = 0.42, p=0.0001). The results of this study, for the first time, demonstrated that that both MS rate and pupil size are affected by the cognitive load during the arithmetic task.

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Visual memory: Precision, capacity

Wednesday, May 15, 8:30 am - 12:30 pm

Poster Session, Orchid Ballroom

63.442 Individual differences in perceptual memory for an ambiguous figure are predicted by individuals' working memory capacity

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Ambiguous figures such as the Necker cube elicit regular perceptual alternations between two appropriate interpretations. Previous work has shown that higher working memory capacity (WMC) may promote perceptual stability of a currently-perceived interpretation. Specifically, higher-WMC individuals experience fewer perceptual alternations of the Necker cube than lower-WMC individuals (Allen et al., VSS2010). A possible explanation is that interpreting an ambiguous figure requires a form of problem-solving or hypothesis-testing (Gregory, 1972), something that higher-WMC individuals excel at during high-level cognitive tasks (Dougherty & Hunter, 2003). Presenting a Necker cube intermittently rather than continuously dramatically reduces perceptual alternations. This phenomenon, a type of perceptual memory (Leopold et al., 2002), is studied here to test whether higher-WMC individuals experience fewer perceptual alternations than lower-WMC individuals under intermittent-presentation conditions. In other words, does higher WMC predict better perceptual memory? Participants indicated perceptual alternations of a Necker cube during 2-min trials from four conditions. In the Continuous condition, the cube was presented continuously, as in Allen et al. (VSS2010). In three Intermittent conditions, the cube was presented for 1 sec and then disappeared for (i) 1 sec (Short-Intermittent condition), (ii) 5 sec (Medium-Intermittent condition), or (iii) 10 sec (Long-Intermittent condition). Replicating previous results, WMC was negatively correlated with perceptual alternations in the Continuous condition (r=-0.31, p<0.02). Additionally, WMC was negatively correlated with perceptual alternations in the Short-Intermittent (r=-0.29, p<0.03) and Long-Intermittent conditions (r=-0.32, p<0.02). Results from the Medium-Intermittent condition approached significance (r=-0.21, p<0.10). Overall, higher WMC did indeed predict better perceptual memory. The results support a novel role for working memory in a lower-level form of problem-solving than is typically associated with WMC. Moreover, they suggest that working memory aids in disambiguating visual information by maintaining an interpretation of a stimulus even when the stimulus is not seen, and without any instruction to do so.

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63.443 Anatomy of early visual cortex predicts visual working memory capacity

Johanna Bergmann[1,2,3], Erhan Genç[2,3,4], Axel Kohler[2,3,5], Wolf Singer[2,3,6,7], Joel Pearson[1]; [1]School of Psychology, University of New South Wales, Sydney, Australia, [2]Department of Neurophysiology, Max-Planck-Institute for Brain Research, Frankfurt am Main, Germany, [3]Brain Imaging Center Frankfurt, Frankfurt am Main, Germany, [4]Institute of Psychology, Ruhr University Bochum, Bochum, Germany , [5]Institute of Psychology, Westfälische Wilhelms University Münster, Münster, Germany, [6]Frankfurt Institute for Advanced Studies, Goethe University, Frankfurt am Main, Germany, [7]Ernst Strüngmann Institute in Cooperation with Max Planck Society, Frankfurt am Main, Germany

Visual working memory (VWM) provides a vital link between sensory input and higher-level cognitive processing and is subject to large interindividual variation. Previous research has suggested that limitations to VWM capacity are set by higher-order areas such as prefrontal, posterior parietal, inferotemporal and lateral occipital regions and their interactions. However, the role of early visual cortex has recently caught the interest of researchers, shedding light on the question how individuals are able to remember more fine-tuned information about a stimulus, such as a grating's orientation. Using a combination of psychophysical testing, functional and structural magnetic resonance imaging methods (MRI), we show that anatomical properties of early visual cortex are also strongly predictive of an individual's visual working memory capacity. In a two-alternative-forced-choice task, we asked our participants to remember the orientations of Gabor gratings that surrounded a fixation point in a circular fashion. Using the standard retinotopic mapping procedure to functionally define the boundaries of early visual cortices in each participant individually, we found that participants' performance in the task was strongly positively correlated with the surface size and cortical thickness of primary visual cortex (V1) and with cortical thickness of secondary visual cortex (V2). That is, participants with a larger V1 or thicker V1 and V2 tended to have a higher VWM capacity. In contrast, we found no such relationship when using a numerical working memory version of the task, thereby confirming the specificity of the observed relationships. Whole brain cortical thickness analyses additionally supported the importance of low-level early visual cortex as a decisive stage for setting individual capacity differences. Our findings insinuate that early sensory areas might play a larger role in shaping individual differences in higher cognitive functions than hitherto thought.

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63.444 The Multiple Change Detection Approach to Estimating Visual Working Memory Capacity

Nancy Carlisle[1](nancy.carlisle@gmail.com), Britta Hahn Hahn[2], Benjamin Robinson[2], James Gold[2], Steven Luck[1]; [1]Center for Mind and Brain, University of California Davis, [2]Maryland Psychiatric Research Center, University of Maryland

Estimates of visual working memory capacity (K) vary widely across individuals (Vogel & Awh, 2008), and correlate with measures of intellectual ability. However, typical measures of K are potentially confounded with attentional lapses. It is unclear whether incorrect responses are due limitations in capacity, or a complete lapse of attention that results in no items being stored in working memory. Recently, methods using multiple set sizes and new analysis techniques (Rouder, Morey, Cowan, Zwilling, Morey, & Pratte, 2008; Morey, 2011) were introduced to dissociate attentional lapses and K. However, there is evidence that participants may exert reduced effort at larger array sizes, leading to a decreased estimate of K (Rouder, et al., 2008). Here, we evaluate a new method of assessing K-called Multiple Change Detection (MCD)-that provides concurrent measures of attentional lapses and K while eliminating differential effort allocation across set sizes (Gibson, Wasserman, & Luck, 2011). Rather than varying the set size and changing a single item, this method keeps set size constant and varies the number of items that change. The number of changes is not known in advance, so observers cannot strategically vary their level of effort. To evaluate MCD, we performed Monte Carlo simulations contrasting MCD and traditional methods for estimating K. MCD-based estimates of K were less distorted by attentional lapses. We applied this new method to people with schizophrenia (PSZ) and healthy control subjects (HCS) to determine whether previous reports of reduced K in PSZ were an artifact of an increased lapse rate. We found that PSZ had more frequent attentional lapses than HCS, but capacity was still reduced in PSZ. By providing separate estimates of attentional lapses and capacity and eliminating the possibility of differential effort allocation across set sizes, MCD provides a promising new method for estimating visual working memory capacity.

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63.445 The Influence of Saccade Execution on Spatial Working Memory Precision

Andrew Hollingworth[1](andrew-hollingworth@uiowa.edu), Seongmin Hwang[1], Steven J. Luck[2]; [1]Department of Psychology, University of Iowa, [2]Center for Mind & Brain and Department of Psychology, University of California, Davis

Several theories posit that visual perception and visual working memory depend on a common selective mechanism—visual attention—that operates over the representation of currently visible objects and previously visible objects. Competing accounts hold that selective maintenance in working memory is dissociable from the locus of visual attention. Here, we tested of the role of visual attention in the maintenance of object locations in spatial working memory (SPWM). Relative to previous studies on this topic, the present method provided a more direct measure of spatial memory, allowed for a continuous estimate of memory precision, and manipulated attention in manner that did not require an additional discrimination task, significantly simplifying inferences regarding the role of visual attention. In the memory-only condition, participants could keep attention focused covertly on a remembered location during retention of that location. Participants maintained central fixation as a memory dot was presented briefly. After a retention interval, participants executed a saccade to the remembered location and pressed a button to report fixation of that location. Memory precision was calculated as the difference between fixation location and memory

Wednesday AM

location. The dual-task condition was identical to the memory-only condition, except, during the retention interval, participants executed a saccade to a peripheral distractor box and back to the center. Because visual attention cannot be maintained at one location as a saccade is planned and executed to a different location, visual attention could not have been maintained continuously on the memory location during the retention interval. The addition of the saccade task produced no observable decrement in the precision of SPWM, despite sufficient power to detect a difference in accuracy of less than 0.05° of visual angle. Precise memory for location is not necessarily dependent on the allocation of visual attention, calling into question a direct, functional relationship between SPWM and attention.

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63.446 Quality vs. Quantity: Strategic tradeoffs in working memory

Sarah Cormiea[1](sarah.cormiea@gmail.com), Daryl Fougnie[1], George A. Alvarez[1]; [1]Vision Lab, Department of Psychology, Harvard University

People can only store a limited amount of information in visual working memory. What is the nature of this limit, and does its expression depend on task demands or is it fixed? Here we show evidence that participants have control over both the quantity and fidelity of items stored in working memory. Participants were briefly shown five colored circles and asked to remember the colors over a short delay, and then responded to one randomly probed item by adjusting the probed item's color using a continuous color wheel. This task affords a measure of the quality and quantity of stored representations (Zhang & Luck, 2008). Consistent with past work we found that participants could store 3.9 objects and that the precision of an object in memory was 22.0° (standard deviation of error over color space). In another condition, we altered the task demands: Participants made a response to all five items and the trial was only considered correct if all responses were within ±90° of the correct answer. In this task, knowing something about all items, even at a poor resolution, is optimal for performance. If strategic manipulation of working memory contents is possible, we expect a tradeoff in performance—participants will store more items but items will be stored less precisely. The results show exactly this; participants stored more items (4.4 vs. 3.9, $p<0.005$) but at worse precision (26.3 vs. 22.0, $p<0.005$). This was true even when participants were not cued whether to report one or all items until after stimulus offset, demonstrating that these tradeoffs cannot be attributed to differences during encoding. These results suggest that observers can strategically tradeoff memory quantity and quality, and that capacity limits measured in standard working memory tasks should be taken to reflect a common strategy, rather than fixed limits on working memory.

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63.447 Looking into training effects on visual working memory capacity: With individualized training and performance trends.

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It still has been in dispute whether or not visual working memory (VWM) capacity improves with training. To resolve this question, the current study investigated training effects on VWM capacity from two unique perspectives. First, we gave trainees individually tailored, adaptive training. Second, we examined individual performance trends developing across multiple training sessions. During the training period, the trainees performed a change-detection task in which one stimulus in a sample array, cued by a left- or right- pointing arrow, could change or not change in color when it reappeared with the others in a test array. Training difficulty was individually adjusted by changing either the number of distractors or the SOA between a sample and a mask array within a training session using the staircase method. The threshold obtained from the previous session determined the starting point of a staircase in the current session. The trainees participated in a total of 10 training sessions over a two-week period and each training session took approximately 10 minutes. Before and after training, trainees performed the same change detection task with difficulty being constant across the trainees. We found that VWM capacity (estimated by Cowan's K) marginally increased after training compared to the pre-training test. However, the amount of improvements in VWM capacity was positively correlated with the number of threshold improvements compared to the previous session during training. In other words, VWM capacity difference between pre- and post-training tests increased, as the number of improved training-sessions compared to the previous session increased. This result suggests that VWM capacity can be enhanced with adaptive training. In addition, the current study presents new ways of training and assessing the capacity of VWM.

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63.448 Enumeration performance modulated by spatial working memory load

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Inspired by Shimomura & Kumada (2011), we investigated if visual working memory load will affect subitizing and enumeration performance. Our dual-task paradigm used a rapid serial visual presentation (RSVP) stream, in which we first taxed participants working memory with a spatial location memory task followed by an enumeration task. We hypothesized that as we increased the difficulty of the working memory task, we would see reduced enumeration and subitizing performance. The RSVP stream consisted of participants being asked to remember a 3x3 matrix containing 3, 5, or 8 alphabet characters, presented for 1000ms. Next, Gabor patches ranging from 0 to 9 were presented for 133ms, and participants immediately keyed in a response. After submitting their response, a second matrix of letters similar or identical to the first was presented indefinitely until participants responded if they thought the matrix was the same or different as the first. This design both divided the participants' attention and taxed their spatial working memory for the duration of the trial. Results show that accuracy decreased with numerosity and working memory load. Interestingly, these factors also seem to be independent, suggesting that interactions between perceptual numerosity and working memory depends on the type of working memory task.

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63.449 Statistical Inferences Depend on Working Memory Capacity Estimates

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Three versions of the change detection paradigm have been used to measure visual working memory (VWM) capacity, 1) whole-display probe, and two types of single-display probes: 2) probe at prior display location and 3) probe at central fixation. Past VWM capacity estimates, K, have often used Cowan's or Pashler's formula regardless of single-item and whole-display probes. However, Rouder et al. (2011) argue that Cowan's K estimate is appropriate for single-item probe, whereas Pashler's K estimate is appropriate for whole-display probe. Additionally, Cowan et al. (2012), have recently reported a third K estimate for a single-item probe presented at the center of fixation rather than at its WM array location. Here we investigate how variations of K-estimate formulae might affect inferences drawn from studies of VWM. WM load (4, 6 items), memory feature (color, shape), and type of probe presented (single-item probe centered at fixation, single-item probe centered at its prior location, whole-display probe) were varied. Cowan's (2001) K estimate, Pashler's (1988) K estimate and a variant of the appropriate estimate to include Cowan et al.'s (2012) K estimate for a single-item probed at the center of fixation were compared. Results indicate that the type of formula used interacts with main effects of Feature, Probe Type, and WM Load; with the two-way interactive effects of Feature x Probe Type, Feature x Load, and Probe Type x Load; and with the three-way interactive effects of Feature x WM Load x Probe Type. These findings indicate that, in multiple ways, the inferences one might draw from results obtained in VWM studies, while also depending on feature to be remembered, depend significantly on the formula used to compute K.

63.450 Low capacity for visual spatial relation memory

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Visual spatial relations are the foundation for encoding information in graphs, diagrams, and maps. While successfully using these displays requires that we extract, remember, and integrate these relations, there is little existing work measuring how many we can store. Some related types of visual information seem to be robustly encoded, such as the 'shape' of the layout of a simple display (Chun & Jiang, 1998; Jiang & Wagner, 2004), or the absolute spatial locations of a set of objects (Hollingworth, 2006). However, these types of information do not explicitly encode the relative locations between objects with different identities. Here we tested memory capacity for relative spatial location between pairs of briefly presented objects, and found that it was strikingly limited. Participants viewed a sequence of three vertically presented image pairs in which each pair appeared for 600ms at one randomly chosen corner of the screen. Participants were immediately tested on their memory, for either object identity or relative spatial location. In the object identity task, participants were instructed to decide which of two images they had previously seen. In the spatial memory task, they viewed one image and identified its relative location (up or down) within the previously studied pair. Participants were not informed about which task they would perform beforehand. While accuracy for identity memory was high (M=92%, SD=9%), accuracy for relative spatial location was significantly lower (M=81%, SD=9%). Memory for relations was low despite displaying only 3 pairs before each test phase, despite the continuous possibility of being tested on the spatial relation task, and despite using top/bottom relations, which are typically easier to extract compared to left/right relations (Logan, 1995). A capacity estimate would place memory for relations at 1-2. Contrary to our intuitions, memory for relative spatial locations was much more impoverished than memory for object identities.

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63.451 **Discarding Information from Visual Working Memory** Melonie Williams[1](melonie.williams@vanderbilt.edu), Geoffrey Woodman[1]; [1]Department of Psychology, Vanderbilt University

Recent research using change-detection tasks has shown that a directed-forgetting cue, indicating that a subset of the information stored in memory can be forgotten, significantly benefits the other information stored in visual working memory. How do these directed-forgetting cues aid the memory representations that are retained? We addressed this question using two approaches. In one approach we used a recall paradigm to measure the nature of the retained memory representations. In the other approach we used event-related potentials (ERPs) to more directly measure what was actively maintained in visual working memory. Our results demonstrate that a directed-forgetting cue leads to higher fidelity representations of the remaining items and a lower probability of dropping these representations from memory. We also show that to-be-forgotten items are expelled from visual working memory following the cue allowing maintenance mechanisms to be focused on only the items that remain in visual working memory. Thus, the present findings show that cues to forget benefit the remaining information in visual working memory by fundamentally improving their quality relative to conditions in which just as many items are encoded but no cue is provided.

63.452 **High and low: The resolution of representations in visual working memory** Tina T Liu[1](liutong@hku.hk), Zhongting Chen[1], William G Hayward[1]; [1]Department of Psychology, University of Hong Kong

Visual working memory (VWM) has long been considered to be limited in capacity, but the way in which it is limited remains unclear. Despite differences in predictions of the number of objects that can be stored, both the slot and resource models agree that resolution in VWM declines as the number of objects increases. Here we investigate the relationship between the resolution of items and the number of items in VWM by separating different types of resolution measures. In this study, we adapted the paradigm of Awh, Barton, and Vogel (2007) to provide separate measures for low-resolution (i.e., categorical judgment) and high-resolution (i.e., within-category fine discrimination) representations of an item in memory. Participants were asked to remember a mixture of objects from two categories, varying in set size and display time. After a 1s retention interval, the location of one item was highlighted and participants were first tested on the category of this item-to-report. The nature of the second response was contingent on the first: depending on which category response was made, participants either adjusted a color wheel or selected a cube from an array (Experiment 1), or reported the color or orientation of gabor patches (Experiment 2). In both experiments, precision of high-resolution representations declined monotonically until the set size reached four items, fitting to the predictions from the standard mixture model of Zhang and Luck (2008). In contrast, we observed that the accuracy for low-resolution representations remained very high and did not decrease with set size, which is not consistent with either model. We propose that the inverse relationship between the number and resolution of representations in VWM is perhaps not the only possible relationship: different types of resolution representation exist in VWM, and people can maintain both high- and low-resolution representations of an object.

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63.453 **Parallel extraction of summary information across multi-element arrays** Jan Balaguer[1](jdobalaguer@gmail.com), Andrei Gorea[2], Elizabeth Michael[1], Christopher Summerfield[1]; [1]Department of Experimental Psychology, University of Oxford, Oxford OX1 3UD, UK, [2]CNRS UMR 8158, Laboratoire Psychologie de la Perception, 75006 Paris, France

Observers are capable of making rapid and accurate judgments of the summary information in an array composed of multiple elements. Whilst some theories have argued that this suggests that the visual system is capable of automatic extraction of statistical information from a visual scene, others have suggested that serial strategies may play a role. To test whether perceptual averaging occurs in parallel or in series, we asked observers to judge the average feature (shape or colour) in a centrally-presented visual array with a variable number of elements ('squircles', i.e. shapes that varied continuously from shape to circle). As reported previously, we found that the variance (heterogeneity) of the array slowed responding and increased error rates, but set size (2, 4 or 8 items) had no influence on performance. Reasoning that it might be possible to average in parallel across information on a single dimension (e.g. shape or colour) but not a conjunction of two dimensions, we devised a new averaging task in which the decision value was continuously signalled by the conjunction of two dimensions, with more red/square or blue/circle items belonging to one category and more blue/square or red/circle items belonging to the other. Surprisingly, for these stimuli we found no influence of the array variability and an inverse set-size effect, with better performance for larger arrays. This latter finding cannot be due to increased precision for larger set sizes (or less variable arrays) because in both experiments elements were pseudosampled to ensure a fixed mean value. Together, these findings suggest that averaging of both one- and two-dimensional information can be conducted in parallel, supporting models suggesting that observers automatically extract summary information from visual scenes.

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63.454 **Perceptual Precision Predicts Visual Working Memory Precision** David W. Sutterer[1](sutterer@uoregon.edu), David E. Anderson[1], Edward Awh[1]; [1]Department of Psychology, University of Oregon

Sensory recruitment models maintain that storage in working memory (WM) is accomplished via activity in the same brain regions that encoded the memoranda (e.g., Serences et al., 2009; Harrison and Tong, 2009). It follows naturally from this hypothesis that encoding acuity may be correlated with the precision of online visual memories, even if encoding quality is not a limiting factor in the memory task. For instance, encoding and storage quality may depend upon a common top-down process that guides internal and external selection. Another possibility, however, is that variance in mnemonic precision across observers is determined by the degree to which mnemonic precision falls below the ceiling set by encoding precision; in this case, encoding and mnemonic precision may not be correlated at all. To test these alternatives, we measured performance in a perceptual orientation task that required participants to match the orientation of two sine wave gradients displayed above and below fixation. In a separate VWM task, we measured visual WM precision while optimizing the encoding conditions for the memorandum. Participants remembered the orientation of a single foveally presented line (duration: 250 ms) and reported the orientation after a 1.25 second delay. Perceptual and VWM response precisions were operationalized by the standard deviation (SD) of the response offset histograms. Critically, perceptual and mnemonic precision were reliably correlated, $r(35) = .537$, $p < 0.001$. Finally, EEG measurements during a visual WM task revealed that neural synchrony in the alpha-band – even when measured during the encoding period alone – provides a robust prediction of individual mnemonic precision. Thus, our findings suggest that a common neural resource may determine encoding and mnemonic precision.

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63.455 **Simultaneously and sequentially presented colors exhibit similar within-task interference for working memory representations.** Garrett Swan[1](gsp.swan@gmail.com), Brad Wyble[1]; [1]The Pennsylvania State University

We can measure how many items working memory can maintain, but how well are these items represented within working memory? One way to measure representational fidelity is through a color identification task in which subjects have to recall and select a color on a color wheel. In such tasks, storing more items results in a reduction in the fidelity of retrieved representations. One potential explanation for the loss of fidelity is that subjects are encoding an ensemble representation of the individual stimuli. To test this hypothesis, colored items were presented simultaneously or sequentially, which we had expected to alter the ensemble statistics. Our hypothesis was that stimuli presented sequentially would have less interference than stimuli presented together. In a series of experiments, three colored squares appeared equidistantly from a focal point, and after a delay, subjects had to select a probed color-memory on a color wheel. To minimize blind guessing, subjects were able to opt out of responding by selecting a box in the lower right corner. In experiment 1, subjects saw 3 colors either simultaneously for 500ms or sequentially presented for 500ms each. In experiment 2, the total duration of the 3 sequential stimuli (166ms) was matched to that of simultaneous condition (500ms). To compare retention durations across different simultaneous conditions, stimuli appeared at either 500, 1000, or 1500 ms from the onset of the trial. Surprisingly, subjects' deviations from the probed color were approximately equal in both the simultaneous and sequential conditions for experiments 1 and 2. These results indicate that the ensemble statistics did not differ between the sequential and simultaneous conditions. The implications of these results are that stimuli presented sequentially are not maintained as separate representations and exhibit interference from ensemble statistics.

63.456 **Whole-report procedures reveal bimodal distribution of visual memory precision within a single array.**

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

Most studies testing models of visual working memory capacity have relied on partial report procedures that probe the observer's knowledge of a single item from a multi-item array. Whole-report procedures have been less common in tests of visual memory, perhaps because of concerns about output interference, but such procedures may provide richer information about within and between-trial variations in memory performance. Here we measured memory performance in a whole-report procedure to test whether output interference was a concern, and to examine the variations in memory quality between items from a single sample array. In a continuous whole-report recall task, participants recalled the color of each item in the array. In Experiment 1, participants freely recalled the color of presented items (set sizes 1,2,3,4, and 6) in any order they wished by selecting each object and then clicking a color on a surrounding color wheel. In Experiment 2, participants responded to the colored items in an order randomly determined by the computer. When subjects were free to recall the items in any order, we observed a bimodal distribution of high and low precision for the first three versus the last three reported items, respectively. Importantly, these differences in representational quality were not due to output interference: In Experiment 2, participants responded to all items in a random order, and no reliable effects of response order were observed. Thus, continuous whole-report reveals strong variations in the quality of memories from a single array. Moreover, the order of observers' free recall is highly sensitive to these variations, suggesting that observers have reliable meta-knowledge of which items are best represented. Whole-report procedures may provide richer information about variations in mnemonic storage both within and across trials. In turn, data from such procedures will provide stronger constraints for formal models of memory capacity.

63.457 **The question is not if you've seen this picture, but when! Recency memory for large image sets is relatively imprecise.**

Stephen Maher[1](stevemaher12@gmail.com), Todd Horowitz[1], Aude Oliva[1]; [1]CSAIL, MIT

Experiments have shown that people can remember a specific object (Brady, 2008), scene (Konkle, 2010; Isola, 2011), or face (Bainbridge, 2012) from a stream of thousands of images, even when intervening images are categorically similar. But how good is their memory for when a given image was presented in the stream? Here, we investigated the temporal fidelity of object visual memory with a large set of images previously used to demonstrate large-scale recognition memory capacity (Brady, 2008). In two experiments modeled after Hacker's (1980) method, observers saw pictures of objects presented individually for 1.3 seconds each. At regular intervals, the image stream was interrupted by a probe trial that required observers to indicate which of two previously seen objects they had seen more recently. We varied both Target lag (time from the first exposure of the target image to the probe trial) and Foil lag (time from the first exposure of the foil image to first exposure of target image). Experiment 1 used a six Target lags (2,4,6,28,30,32) by 3 Foil lags (2,4,6) design, while Experiment 2 used seven Target lags (2,4,6,16,28,30,32) and two Foil lags (13,26). Results from both experiments showed that recency memory for images declined sharply and logarithmically with Target lag. In contrast, Foil lag exerted a relatively small (though statistically significant) effect on performance, accounting for less than 2.5% of the variance compared to ~30% for Target lag. These results are consistent with a self-terminating backward memory search (Hacker, 1980). Observers may have good memory for what they saw in a stream of images, but not for when they saw it.

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63.458 **Comparing memory for colored patches, image textures, and photographs**

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Humans can view and remember thousands of natural images with a remarkable degree of accuracy (Brady, Konkle, Alvarez & Oliva, 2008). However, memory for simpler stimuli is much less robust. What image parameters are required to support massive memory capacity? Here we present an initial exploration for three types of images: colored patches, image textures, and object photographs. Stimuli were presented on a color-calibrated monitor. Color patches were uniform, and were chosen by: (1) identifying 16 points that sampled uvY color space and (2) choosing chromaticity values sampled equidistantly from concentric rings around each of the 16 points. Color patches were clearly discriminable from each other. Image textures were close up color images of real-world objects chosen to lack obvious cues to object identity or scene, such as clothing swatches. Photographs were black and white versions of objects shown on backgrounds. All images were identically sized and subtended ~ 5 degrees of visual angle. Task: For each image type, observers (n = 25) completed an exposure task and a memory task. During the exposure phase, observers viewed exemplars for one second each and instructed to remember them for later testing. The memory task was a 2AFC task in which observers were simultaneously shown one familiar image and one novel image of the same type. Observers chose the novel image on each trial. Results: Performance for objects was similar to performance previously reported for colored natural images (.93 +/- .01). Performance for colored patches was not different from chance (0.53 +/- .02), and performance for textures was intermediate (0.83 +/- .02). Reaction times for natural images were significantly faster than for colored patches or textures, and there was no difference between colored patches and textures. These data provide some constraints on the mechanisms subserving visual memory capacity.

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